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FPL '67

Annual Report of Research at the Forest Products Laboratory

FOREST SERVICE U.S. DEPARTMENT OF AGRICULTURE

foreword

Progress at FPL during 1967 marked the year as one of unusual vitality. Not only was this evident in the gains recorded by research; there was a vigorous growth in the physical plant as new buildings and equipment came into use, with all this implies for future advancement of knowledge. And there was growth and maturation of FPL responsibilities and opportunities to contribute to the solution of complex problems, economic and social, that confront the Nation and the world.

In this report, therefore, it is worthwhile to review briefly the purpose of FPL. Within the broad purview of the Department of Agriculture and the Forest Service, this objective remains essentially what it always has been: to extend the usefulness of wood for the benefit of man. In this time of complex and demanding social ferment, however, new and urgent responsibilities have been thrust upon FPL.

Secretary of Agriculture Orville L. Freeman has focused the Nation's attention upon a phenomenon of our time that has deeply influenced our social evolution: the continuing shift of population from rural to urban centers. To slow, halt, and reverse this trend, the Secretary has called for a rebuilding of rural America.

Forest-based industry is a foundation on which this rebuilding can proceed in many rural areas. A major task of FPL now is to help forest-based industry achieve this economic and social rebuilding, by providing the indispensable science and technology. Thus a social responsibility has been added to the essentially economic objective of FPL research. That research must be planned and executed to contribute maximum benefit to a Nation — yes, and a world — in which social justice still eludes so many. It is in this context that you are invited to read this annual report for 1967.

Herbert O Fleischer

H. O. FLEISCHER
Director

the cover

Research in wood quality, which greatly affects its utility, is represented by the section of ash wood depicted on the cover. The log cross section is from a tree felled some 35 years after it had been fertilized with nitrogen scattered on the soil beneath it. Time of fertilization is clearly shown by the sudden acceleration of growth as represented by much wider annual growth rings. The wood was evaluated for quality in terms of hardness, machineability, and other properties. The tiny sprout in the flask is a stem shoot grown from undifferentiated callus (living cambium) in the laboratory by manipulation of hormones, in far more sophisticated research to study the effects of nutrients upon wood development.

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1967 in retrospect

It was a year of new leadership and of dedication to new and broader goals for the men and women of FPL.

Dr. Herbert O. Fleischer returned as Director to the Laboratory he had left only a few years before to serve as Director of the Division of Forest Products and Engineering Research in Washington, D. C., headquarters of the Forest Service. He came back April 23 as successor to Dr. Edward G. Locke, who had passed away December 19, 1966.

Dedication of two new buildings—the first major additions to the 57-year-old Laboratory since 1932, when its present main building was occupied—provided a fitting occasion for renewal and redirection of the Laboratory's long-time goals. Dr. George L. Mehren, Assistant Secretary of Agriculture, broadly sketched the scope and objectives of FPL research as he delivered the dedicatory address beneath the massive wooden arches of the new pilot plant.

"I charge all who work in this splendid structure to hear and heed its challenge . . . to apply themselves to their tasks with the same clear foresight and scrupulous dedication that imbued those who made its creation possible.

"Drawing inspiration from the achievements of our predecessors, let us dedicate this building and its companion to a continuing diligent pursuit of knowledge—to science in the service of man."

Pointing out that today 70 percent of the United States population lives on 1 percent of the land, Dr. Mehren declared:

"This constitutes a social problem of the first magnitude, as evidenced by the past summer's riots, armed clashes, killings, and burnings.

"Secretary Freeman has called for a reversal of this human tidal flow, back to rural areas where man can be free from congestion, smog, and existence in multi-storied apartments or decaying tenements.

New buildings dedicated November 8 were a 460-foot-long pilot plant for pulp and paper experiments and adjoining laboratory-office structure. Main building is shown in left background.

M 133 780

"Can we find here some means of helping stem and reverse that tide of frustrated humanity?

"I believe we can. I think this building in which we are gathered this afternoon may have some part of the answer to this problem. . . An obvious need is for rural-type industries to provide jobs. With jobs will come the amenities and abundance that are the hallmark of our civilization."

To help build rural forest-based industries, Dr. Mehren called for more productive forests, more efficient utilization, and reduction of waste and associated pollution.

On the same theme, Gene C. Brewer, New York City, president of the U.S. Plywood-Champion Papers, Inc., and board chairman of the National Forest Products Association, told a banquet audience climaxing the dedication that past research has shown that new forest products industries can provide jobs in many rural towns.

"The direct benefits of past Forest Products Laboratory research," he said, "as used so effectively in these new buildings, aptly demonstrate its own contribution to the national effort to provide jobs at the community level."

The glued laminated wood arches and stressed-skin plywood wall panels used in the new pilot plant, Brewer noted, were made in rural towns—Peshtigo, Wis., and Lester Prairie, Minn. Future research and development, he predicted, will bring jobs and prosperity to "many future Peshtigos and Lester Prairies." Mr. Brewer called for continuing research "to keep wood, man's oldest building material, as new as tomorrow."

The dedication ceremony was the occasion for the gathering in Madison of many FPL "alumni," research leaders, educators, and prominent figures in government and industry. Among them, a sprightly white-haired woman became a center of attraction. She was Mrs. McGarvey Cline, widow of the Laboratory's first director. Mr. Cline is generally acknowledged as the Forest Service man who conceived the idea of a central forest products laboratory at a time when no such institution existed in the world, and negotiated its establishment in cooperation with the University of Wisconsin. Mr. Cline died in 1965 at his home in Jacksonville, Fla. Mrs. Cline attended not only the dedication ceremonies on November 8 but a technical conference that preceded them.

As part of the ceremony, a specially furnished room in the new laboratory building was dedicated as the Edward G. Locke Memorial Seminar Room in memory of the late Director. Industry, associations, and friends contributed to a fund set up to purchase the furnishings.

Dr. Fleischer had been director hardly three months when he was honored for accomplishments while a member of the Laboratory's research staff. At the annual meeting of the Forest Products Research Society in July, he received an award sponsored jointly by the Society and Woodworking Digest for his "outstanding contributions of specific benefit to the (forest products) industry." The award singled out research he had done to help pave the way for a southern pine plywood industry that since 1964 has flowered throughout the South, with some three dozen mills now operating or under construction.

Among other staff members accorded recognition

Assistant Secretary of Agriculture George L. Mehren delivered the dedicatory address under the massive wooden arches of the new pilot plant. M 133 577 No. 3

Principal speaker at the Dedication banquet was Gene C. Brewer, President, U. S. Plywood-Champion Papers, Inc.

William H. Aiken, Vice President for Research and Development, Union Camp Corp., and President of the Technical Association for the Pulp and Paper Industry, was toastmaster at the Dedication banquet.

M 134 559

for outstanding work was Edward G. Kuenzi, FPL engineer in charge of research on design criteria. In a letter from the Department of the Air Force Flight Dynamics Laboratory at Wright-Patterson Air Force Base, Ohio, Mr. Kuenzi was cited for his "outstanding contribution made to Aerospace Weapons Systems and Air Force Exploratory Development Programs in the field of structural sandwich composites." The citation continued:

"The careful attention and patient endeavor which he gave to these projects reflect most highly on his professional competence and acumen. All of his efforts have been motivated by an intense desire to strive for perfection and to complete the efforts well within the allotted time periods.

"Particularly commendable is the tremendous effort which Mr. Kuenzi put into the writing of MIL-HDBK-23, 'Composite Construction for Flight Vehicles,' and into the MIL-HDBK-23 Working Group meetings. These efforts are typical of the outstanding job performance and exemplary effort which elicited this citation."

Awards for international service were received by two FPL staff members. Forrest A. Simmonds, a senior pulp and paper research expert, and Kenneth H. Boller, a research engineer, were honored with certificates of merit by the Philippine Forest Products Research Institute. The certificates were in recognition of "dedicated service and enduring contributions to the Forest Products Research Institute" during its early organizational development in the mid-1950's, when Boller served as a consultant on timber testing and Simmonds as a consultant on pulp and paper technology.

One of the Laboratory's most widely known scientists, Arthur Koehler, died July 16, 1967, at his home in Los Angeles, Calif., where he had lived since retiring in 1948. Mr. Koehler gained fame by tracing the origins of the wood in a ladder used by Bruno Richard Hauptmann to kidnap the infant son of Charles A. Lindbergh in 1932. His testimony, based on painstakingly acquired evidence, was generally credited with playing a decisive part in the conviction of the Bronx, N.Y., carpenter at a hectically publicized trial in 1935 at Flemington, N.J.

Mr. Koehler joined the Laboratory staff in 1911 as chief xylotomist, or identification expert. For many years he headed the Laboratory's wood identification service and was chief of the Division of Silvicultural Relations, which he organized. His pioneering research on wood structure helped lay a firm basis for identification techniques now widely used.

Outstanding among activities at FPL during the year was the complex and difficult task of transferring a great array of research equipment to the new pilot plant and laboratory for research on wood fiber

Dedication ceremonies at the U.S. Forest Products Laboratory in Madison, Wis., November 7-8 brought many "alumni" of the federal research institution together again. This group huddled briefly between technical sessions to reminisce. From left are Richard J. Auchter, acting chief of the Laboratory's wood fiber research division and former research official with Kimberly-Clark Corp., Neenah, Wis.; John N. McGovern, one-time FPL pulp research specialist now vice president of Parsons and Whittemore, New York consulting firm to paper manufacturers; H. Dale Turner, former FPL scientist now director of research, Dierks Forests, Inc., Hot Springs, Ark.; George E. Mackin, who left FPL to become executive vice president of Green Bay Packaging, Inc., Green Bay, Wis.; Herbert O. Fleischer, present Laboratory director; and Clark C. Heritage, Tacoma, Wash., industry consultant who was chief of pulp and paper research at FPL from 1927-30. The conference was part of a dedication ceremony for a new $4 million facility for wood fiber and chemical research.

products and wood chemistry. The task was virtually complete when the dedication ceremony was held in November.

Important progress was also made in continuing expansion of FPL's physical plant. Congress voted funds for a $1.3 million building for wood chemistry research which will be the third unit of the new complex and will adjoin the laboratory building completed during the year. Work was also pushed on plans for remodeling the main Laboratory building to make more efficient use of space vacated by research units moving to new quarters. Among other planned innovations will be a new conference hall for large groups.

Eventually a third phase of expansion will add still another new building—for solid wood products research. When this program of modernization is completed, the Laboratory's capability for serving as the national Forest Service center for research on wood will be greatly improved.

Research progress during 1967 is summarized in the following pages.

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WOOD CHEMISTRY RESEARCH

On subjects seemingly as unlikely as beeksteaf production and the prediction of a wood product's probable service life, FPL chemists made significant progress during 1967 — demonstrating once again the broad capability of chemistry for advancing the utility of wood.

New light on wood's beefsteak potentials was derived from research on its feed value for cattle. The possibility of developing a chemical yardstick for measuring service life probabilities of wood and wood products emerged from research on accelerated aging techniques. Among other developments in wood chemistry research were these:

1. Use of X-ray fluorescence for identifying and measuring amounts of inorganic chemical preservatives in wood.

2. New information on chemical reaction mechanisms of wood carbohydrates, obtained by hydrolysis of model compounds tagged with radioactive carbon atoms.

3. Demonstration that the fiber saturation point of wood is substantially increased following certain chemical treatments and that such treatments, which put wood in a superswollen condition, have significant utilization implications.

4. Conclusive evidence that microbial degradation of lignin is possible only in the presence of cellulose, since micro-organisms producing degrading enzymes cannot exist on lignin alone.

5. Development of a standardized and simplified nomenclature for groups of nonpolar organic compounds extracted from bark.

From a fistulated Holstein, University of Wisconsin graduate student Roger Mellenberger removes stomach contents for use in FPL experiments to determine digestibility of various normal and modified woods.
M 134 424 No. 2

Wood as Livestock Feed

Research during 1967 made it clear that wood can, and probably will, play an increasingly important dual role for livestock feeding—as a roughage and as a source of carbohydrate.

The research was conducted by FPL chemists in cooperation with investigators at the University of Wisconsin, Penn State University, and Auburn University. At all three universities, livestock is being used in the experiments. Funds for the work are being supplied by FPL and the Tennessee Valley Authority, which has broad interest in finding ways to expand utilization of extensive timber holdings in its area.

Interest in the possibilities of wood for livestock feeding has arisen from the expanding practice of feeding beef cattle highly concentrated diets of grain, molasses, and other feeds for rapid weight gains. The digestive systems of cattle and other ruminants—cud chewers—are not geared for such diets, however, unless accompanied by roughage, usually hay. This is because the concentrated feed is utilized by micro-organisms in the first stomach, which produce fatty acids, such as acetic and butyric acid. Chewing of roughage stimulates flow of saliva, which contains sodium bicarbonate. This neutralizes the stomach acids. Unless fed roughage, the ruminant develops a sour first stomach (rumen)

Test tube samples of sawdust incubated in gastric juice of a cow are removed from centrifuge by Andrew J. Baker, FPL chemical engineer, for determination of amount of wood digested.
M 134 435 No. 2

Rack of wood specimens is lowered into accelerated aging chamber by Dr. M. A. Millett.
M 134 340 No. 11

and digestion is upset, with deleterious effects on weight. Also, the animal's liver may be damaged.

Interest in wood as roughage has stemmed from the fact that much livestock is finish fed with high-concentrate diets at large yards. Some yards are located in areas where hay is scarce and costly, but wood is relatively plentiful. Experiments under way at Penn State and Auburn show that sawdust mixed with feed grain provides a satisfactory roughage. These experiments are continuing.

Unfortunately, however, the animal's digestive system cannot assimilate the carbohydrate in wood as it does that in hay. This is believed to be because wood contains much more of a cementlike non-carbohydrate substance called lignin than does hay. When lignin is removed, as in pulping, the cellulose remaining is much more digestible. Wood pulp, however, is far costlier than hay—$150 a ton, compared with $20 or so for hay.

Working with University of Wisconsin scientists, FPL chemists began experiments with less costly methods of making wood carbohydrate more readily digestible. For these experiments, samples of digestive juices are taken from a cow's rumen. In effect, an artificial rumen of test tubes is used to incubate a mixture of the digestive juices and an artificial saliva in which a sample of hay, aspen sawdust, or cotton is placed. After 48 hours, the residue of the sample is washed, dried, and weighed. The difference in weight between the original and the residue tells how much was digested. Wood sample residues are also tested for carbohydrate content to determine how much was used.

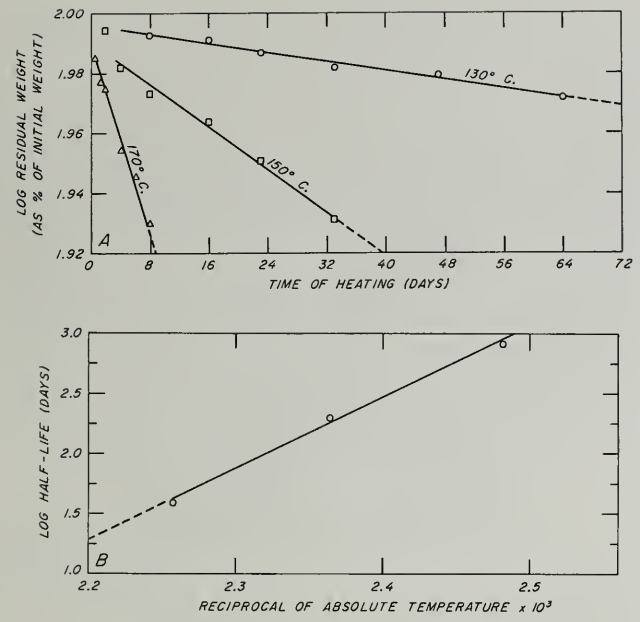
Among wood samples being thus compared for digestibility with hay and cotton (relatively pure cellulose) are woods treated to increase accessibility of carbohydrate. Low-cost ammonia and alkali treatments have been found to about double the amount of carbohydrate utilized in aspen sawdust. These treatments tend to swell the wood at room temperature, making it more readily assimilable by the digestive juices and their associated bacteria and other flora.

Aspen appears to be one of the few woods that are somewhat digestible without treatment. Some evidence has been found that this is due at least in part to the presence of tension wood, an abnormality which consists of gelatinous fibers that contain relatively little lignin. Aspen is also relatively free of extractives, which can interfere with digestibility.

The experiments with slightly modified woods are continuing.

Accelerated Aging

Experiments on the controlled heating of wood to greatly accelerate the aging process, as measured by weight and strength losses, are showing promis-



Weight losses sustained by wood specimens at various temperatures (upper graph) are used to derive generalized expression (lower graph) giving half-life as function of temperature.

M 130 632

ing results. The object of the experiments is to develop means of predicting service life of wood products. The research is a development from earlier studies on paper and a commercial fiberboard ceiling tile that had shown definite rates of change with controlled heating at various temperatures.

Three hardwoods and three softwoods are being used in the experiments. Specimens are heated for prescribed periods at different temperatures, then weighed and tested for static bending strength. Both strength and weight drop sharply and at a constant rate at the higher temperatures. Strength falls off faster than weight, as expected, since only a small change in weight can cause appreciable strength losses. Proportionally, however, weight and strength losses are reasonably constant. Both behave as though they follow a first-order chemical rate equation. That is, the ratio of the logarithm of residual weight to that of residual strength, when plotted against time, produces a fair straight line when the natural variability of wood is taken into consideration.

Carbohydrate Reactivity

The complex reactions that take place in wood carbohydrates during chemical processing, as in pulping, are being learned through a process of simplification that takes up one aspect at a time. This is being done by experiments with relatively simple model compounds that represent parts of the carbohydrate fraction.

One such model compound recently studied is cellotriose, a cellulose fragment consisting of three glucose units with two glycosidic bonds. The mode of hydrolysis of this compound under acid conditions was determined by fixing a radioactive carbon atom at the reducing end of the molecule. The glycosidic bond at the nonreducing end proved to be the preferred point of attack; the bond hydrolized 1.5 times as fast as the bond at the reducing end.

On the other hand, cellotriose similarly tagged with radioactive carbon was attacked by enzymes almost exclusively at the nonreducing glycosidic bond.

Object of the work is to obtain a more intimate knowledge of the many reactions that take place during pulping and other processing, so that closer control can be exercised and greater quantities of more useful products obtained.

Associated with this work is research aimed at developing more exact methods of analyzing intermediate and end products of carbohydrate processing. A rapid spectrophotometric procedure was developed for quantitative determination of both sugars and uronic (sugar) acids, and a thin-layer chromatographic technique is under development for separation of the acidic constituents of xylan hydrolyzates.

Prehydrolysis Rates

Not all hardwoods can be prehydrolyzed in the same period of time to remove certain pentosans, notably xylan hemicellulose, before being chemically pulped. This was shown in experiments with elm, which required a substantially longer prehydrolysis than most hardwoods. At least part of the reason was found to be an unusually high ratio of glucuronic acid to xylose in the pentose fraction of this species.

X-Ray Analysis of Preservatives

Both the kind and quantity of some inorganic preservatives in treated wood can be quickly determined by a new X-ray technique under study by FPL radiologists. The technique is known as X-ray fluorescence. X-rays beamed on a specimen of treated wood induce others of secondary wavelengths to fluoresce from the specimen. The wavelength of the secondary beams is determined by means of a crystal whose atoms are spaced a known distance apart. This spacing, together with the angle at which the beam is reflected, identifies the wavelength.

Various inorganic chemicals used as preservatives toxic to decay fungi that attack wood can be identified by the wavelength of the X-rays they fluoresce. Arsenic, for example, fluoresces at an X-

FPL chemist Ruth Steffes places a specimen of wood preservative in X-ray spectrometer for fluorescence analysis.
M 134 340 No. 9

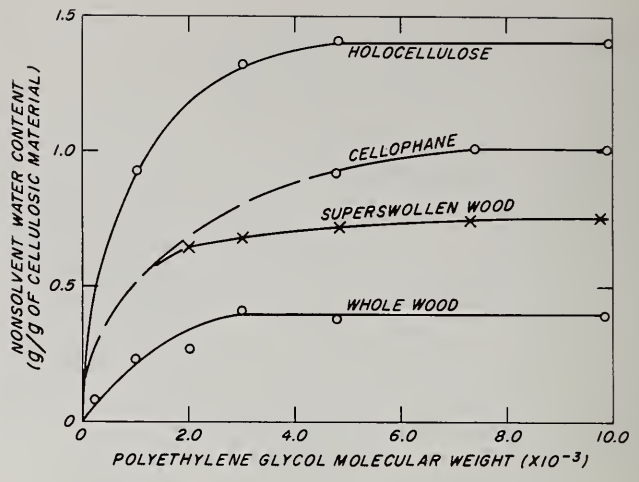
ray wavelength of 1.18 angstroms, zinc at 1.44 angstroms, copper at 1.54 angstroms, and chlorine at 4.73 angstroms. The intensity of the fluorescing beam is a measure of the concentration of chemical in the wood.

The experimental technique gives strong promise of greatly simplifying and speeding up what hitherto has been a long and tedious chemical assay.

Fiber Saturation Point

Firm evidence that wood pulp, paper, and even alkali-modified hardwood have much higher fiber saturation points than normal wood has been obtained in experiments with a new method of ascertaining this property. The fiber saturation point of wood is the point at which the cell walls are saturated but the cell cavities remain free of water. It is critically important as the starting point of shrinkage during drying. Various methods, none entirely satisfactory, have been used to determine it in wood; 30 percent moisture content is the generally accepted fiber saturation point of normal wood. The same methods, however, have not been usable with pulp or paper. It has been assumed that these matrials have about the same fiber saturation point as wood.

From experiments to measure the size of the openings in the fiber walls that permit solutes to enter, a new method of determining the fiber saturaton point has been conceived. The size of the openings was measured by soaking green wood in solu-



Fiber saturation point of wood (hard maple), superswollen wood, cellophane, and holocellulose as determined by new FPL method.
M 133 195

tions of polyethylene glycol of various molecular weights. The greater the molecular weight, the larger the opening necessary to permit it to enter the fiber wall. At a molecular weight of 3,000, diffusion of polyethylene glycol into the fiber wall of normal wood was for all practical purposes blocked. This fact pointed the way to a method of determining the weight of the water in the saturated cell walls of a given wood sample as a percentage of the weight of the wood — in short, the fiber saturation point.

The method used has been to soak green wood in a solution of polyethylene glycol of a molecular weight too large to penetrate the fiber walls. The polymer does, however, diffuse into the water in the fiber lumen. The wood is then removed from the solution and all the water and polyethylene glycol are extracted. The weight of the water taken from the lumen is determined by assuming that it contained all of the polyethylene glycol that entered the fiber and was therefore of the same concentration as the treating solution. The weight of the water removed from the fiber wall—called nonsolvent water — is thus readily determined, and this weight is used to calculate the fiber saturation point.

This method was found to work also with holocellulose, the total cellulose-hemicellulose component of wood, and cellophane, which is virtually pure cellulose. Experiments with these materials showed that their fiber saturation point is much higher than that of normal wood. Hardwood modified by a very mild alkaline treatment — called superswollen wood — likewise was found to have a much higher fiber saturation point than formerly assumed. These observations help explain why paper when wetted retains much less of its dry strength than does

green wood as compared to dry wood.

Curiously enough, the research brought out that the fiber saturation point of a softwood does not rise like that of a hardwood when treated with dilute alkali and then washed with dilute acetic acid and water to bring it to the superswollen state. It is conjectured that this may be the reason why cold soda pulp cannot be made from softwoods. The wet strength of superswollen hardwood is only half that of a normal hardwood. Superswollen wood is also more rapidly decayed by both brown and white rotters. This suggests that other organisms, notably those in the rumen of cattle, might digest it more readily than normal wood, thereby converting it to energy much as hay is utilized. This is being investigated as described elsewhere in this section under the heading, "Wood as Livestock Feed."

Lignin Research

The main objective of FPL lignin chemistry research is to learn the molecular structure of this ubiquitous substance of trees, so that more efficient means of removing it can be devised and uses for it developed. During 1967 further slow progress was made toward eliciting its complex structure, which is known to be radically altered by existing chemical processes for separating it from the carbohydrate fraction of wood, as in pulping.

Evidence was obtained that the ester group present in lignin, hitherto thought to be introduced by secondary reactions, probably is an intrinsic part of the lignin polymer. Work with simplified model compounds representing parts of the lignin molecule also traced the mechanism of formation of an unusual dioxepin structure by enzymatic dehydrogenation of one of these models, alpha-ethyl-vanillyl alcohol. This type of compound had not been suggested before as part of the lignin structure. That it is, however, is strongly indicated by the fact that, when treated with dilute acetic acid, it develops colors reminiscent of those produced by extracted wood meal similarly treated.

Model compounds are also being employed to learn how enzymes of fungi degrade lignin, eventually reducing it to humic acid. This is known to occur constantly in nature as a housekeeping operation in the forests. More exact knowledge of the oxidizing process involved would, it is believed, be of aid in reducing pollution of streams by pulpmill effluent and other discarded wood substance. In the course of these experiments, it has been definitely shown that the enzyme-producing fungi cannot subsist on lignin alone, but must consume cellulose also.

Dr. Chen-Loung Chen adjusts evaporator used to condense acetone extractives of wood used in lignin chemistry research.
M 134 340 No. 7

New Nomenclature System

Extractives research on pine barks has yielded many compounds during the past several years. An extra dividend from this research has been the development of a simplified standardized nomenclature for groups of compounds, some of which defy description by the nomenclature now in use around the world. The new system will be submitted during 1968 to the International Union of Pure and Applied Chemistry for consideration as a replacement.

Manual for Wood Chemical Analysis

Methods found reliable, useful, and accurate by FPL for analytical work have been compiled in a manual entitled, "Procedures for the Chemical Analysis of Wood and Wood Products," by Wayne E. Moore and David B. Johnson. Data on the composition of wood and related information are included. A small number of copies are available for limited distribution.

NU-FRAME...

A new kind of house goes up

FPL engineers built the prototype of the Nu-Frame componentized house system at the building research park.

1. Workmen assemble a wall.
2. A sheet of aluminum-faced fiberboard is laid in place on studs.
3. Crane lifts a dual-chord truss.
4. Metal plate connects truss to wall plate. Note sound-proofing holes in wall diaphragm.
5. Building adhesive is spread on truss for roofing component.
6. Joint between lengths of sheathing-roofing component is sealed with polyvinyl fluoride tape.

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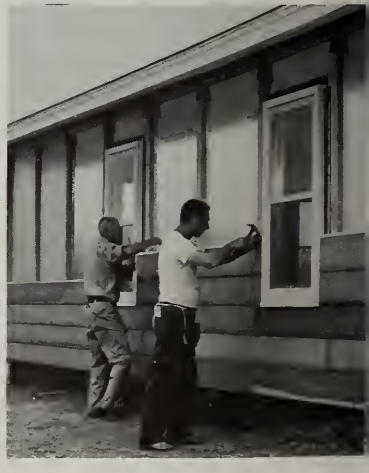

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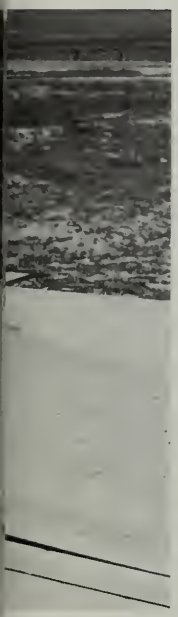
7. One type of wall component, consisting of sheathing and siding bonded together with adhesive.
8. Installing sheathing-siding component.
9. Interior wall component is prewired with thermocouple for temperature readings during life of building to measure insulating efficiency.
10. Installing interior wall component.



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WOOD ENGINEERING RESEARCH

Research in wood engineering during 1967 covered the complete spectrum from highly theoretical to tangibly practical. Work ranged from exploration of concepts of crack propagation and residual stress effects in curved beams to the construction of a full-scale house embodying a new system of wall and roof components. Among other developments in FPL engineering research during the year were these:

1. Experimental verification of the tensile strength of visually graded dimension lumber.
2. An analysis of stresses in a hyperbolic paraboloid roof.
3. Establishment of basic strength properties of two Hawaiian-grown species.
4. A simple new patented method of tape closure for triple-wall containers.
5. Analysis of the impact strength of several species for use as highway guard posts.

The year in enginering research was also marked by a probing analysis of several specimen sampling and collection methods and an investigation of the possibilities of automating procedures for strength testing and data analysis. Both studies are aimed at producing more per research dollar.

Nu-Frame House Built

A prototype house incorporating the new design concepts and structural components of the Nu-Frame system of house construction was erected in the Building Research Park. (The system was described in the 1965 Annual Report.) A number of other innovations were also introduced, among them experimental foundation and subfloor systems. Conventional and experimental wood floorings are to be installed; the latter will include press-dried strip floors (see discussion of press drying research under "Solid Wood Products Research").

The full-scale Nu-Frame house was erected for a two-fold purpose: To demonstrate its feasibility from a practical construction standpoint, and to evaluate the structural, thermal, acoustical, and other properties of the various components and the structure as a whole. The unique sound-deadening feature incorporated in the fiberboard diaphragm of the walls, for example, will be exhaustively tested for performance under various conditions. Likewise, the thermal-insulating and moisture-vapor-excluding capabilities of the wall components will be under constant surveillance with electronic equipment that was installed when the house was assembled.

Structural adequacy will be watched with special interest because of the extensive use of adhesives in the shop-fabricatd components and in site assembly of the whole structure. Only a small fraction of the number of nails ordinarily used to assemble a house was used in the Nu-Frame structure.

Although this is the first house of Nu-Frame design ever built, FPL engineers had made extensive evaluations of the strength and other properties of the various components beforehand. One object of the Nu-Frame design is to make much greater use of relatively low-quality boards than is usually practical in houses of conventional design. This object has been substantially attained. It thus opens the way to more efficient commercial use of the total production of lumber from second-growth timber, which is usually harvested at a much younger age and in smaller sizes than the original mature timber of the Nation's forests.

Trussed Rafter Performance

The increasing use of trussed rafters — more commonly called roof trusses — in housing has prompted a 15-year investigation of the performance of these structural elements under changing environmental conditions but constant load. Twenty-one full-size trusses built of nominal 2 by 4 lumber to 28-foot span and with a pitch of 4 inches to every foot of span, were loaded to the equivalent of a roof load of 26 pounds per square foot. The trusses differ from one another in that some are joined together with nailed plywood gussets, some with plywood

These trussed rafters are undergoing 15-year loading test to compare rigidity of various types of joint fastenings.
M 134 435 No. 11

gussets nailed and glued in place, and some with three types of metal truss plates. Deflection under long-time load will be the principal criterion for comparing the performance of the various types of connector systems used.

New Light on Tensile Strength

Discovery of a method of testing full-size wood members in tension without crushing the parts held in grips of the testing machine has (see 1964, 1966 Annual Reports) permitted experimental establishment of true tensile strength values. Until this became possible, it had been generally assumed from tests of small, clear wood specimens that the tensile strength of wood was approximately the same as its bending strength.

Results of tensile tests of southern pine lumber by the new FPL method have now shown, however, that tensile strength is affected differently than bending strength by growth characteristics. Design values arrived at from that study were about 40 to 75 percent of the assigned value for a given bending-strength grade, with lower ratios occurring in the grades assigned lower bending stresses.

These findings are expected to lead to use of more accurate tensile stress values in the design of wood structures in which tensile strength is dominant. Committee D-7 on Wood, American Society for Testing and Materials, has recommended that tensile working stresses for visually graded dimension lumber be held to 55 percent of the assigned bending stress unadjusted for size (or two-thirds of the currently used bending working stress). It is expected that further consideration will lead to assignment of tensile stress on the basis of grade, with proportionately lower stresses given the lower grades and somewhat higher ones assigned the better structural grades of a species.

The impact of these findings is not expected to be great upon the trussed rafter industry, which now uses about 10 percent of the lumber that goes into housing construction. Within the spans generally employed in the industry, which seldom exceed 28 feet, the 2 by 4 has adequate tensile strength for use in trussed rafters. For trusses spanning 32 feet or more, it may be necessary to go to 2 by 6 dimension, FPL engineers believe.

Hyperbolic Paraboloid Stress Analysis

The hyperbolic paraboloid has become a popular shell design for roofs of churches and various kinds of commercial and recreational buildings. It couples high strength with minimal structural support. Its saddle shape, however, makes stress analysis for various types of loads highly complex. Winds, for example, induce both direct and suctional, or uplift, loads on various parts of the surface simultaneously.

Model of hyperbolic paraboloid roof is studied by Paul M. Jenkinson, FPL research engineer who conducted stress analysis of its complex shape under wind loads.
M 134 376 No. 9

Experimental wood pallets with deckboards mastic-bonded instead of nailed to the posts were put into actual service tests at a cooperating brewery late in 1967. Here the forks of a lift truck are about to pick up a mastic-bonded pallet loaded with 42 cases of canned beer weighing 1,911 pounds.
M 134 375 No. 7

An analysis of shear, tensile, and compressive stresses induced by wind and snow loads was completed during the year by FPL engineers for a roof 15 feet square in top plan view. (Total roof area is of course much greater because of the compound curvature and the angle of tilt from lowest to highest corner.) Stresses were determined for winds ranging from 40 to 80 miles an hour, striking the roof surface from four directions — directly across two sides and two corners. Winds blowing from the opposite sides and corners would of course be mirror images of those used in the calculations.

The loading distribution assumed was a 10 by 10 grid pattern with loads calculated at the center of each grid unit. The highest loading calculated for the entire roof was a net vertical uplift load of 4,000 pounds for an 80-mile wind — enough to lift such a roof from its supports unless adequately tied down. The largest uplift load calculated for any single grid unit was 217 pounds.

Experimental verification of the analysis will be undertaken on an actual roof of the design used in the calculations. The roof, together with supports and a structure needed to apply loads, is being designed. The roof cover will consist of $\frac{3}{8}$-inch plywood strips basically 2 feet wide but varying in width to provide straight lines at the overlaps, and scarf jointed to extend in one piece across the full span. Edge beams will be laminated to facilitate bending them to the proper twist to accommodate the plywood covering strips.

Direct loads will be applied by weights suspended from the roof. Uplift loads will be applied from rafters of a loading structure built over the roof.

Hawaiian Woods

Two more wood species grown in Hawaiian plantations were evaluated for basic physical and mechanical properties. They are *Albizia falcata* and *Eucalyptus pilularis*. The Albizia species has properties similar to those of ponderosa pine, a native United States softwood widely used for millwork and cabinetwork. The eucalypt has properties similar to those of shagbark hickory, a dense, heavy United States hardwood.

Evaluation of species grown in Hawaii is being done to provide a basis for greater use of homegrown wood. Almost all the wood now used in that State is shipped from overseas. Shipping costs from the mainland United States run $40 per thousand board feet.

Appalachia Highway Guard Posts

Appalachian oak and hickory posts should serve as well for highway guardrails, fences, and signs on the basis of their static and impact properties, as the southern pine posts commonly used, a newly completed evaluation by FPL engineers indicates. Some 476 posts of the three species were used in the study. All had been cut from trees grown within 65 miles of Princeton, W. Va., and furnished by the Forest Products Marketing Laboratory there. Posts were evaluated for static and impact bending

New patented tape closure method for triple-wall fiberboard boxes is essence of simplicity. Upper, installing loop of tape in slot cut into lower flap. Lower, slitting loop before attaching pressure-sensitive tape to top of upper flap. M 133 978 No. 8 M 133 978 No. 4

strength in the green, air-dry, and preservative-treated condition.

Insulating Value of Containers

A theoretical procedure for computing the thermal properties of an infinite variety of corrugated containerboard constructions without time-consuming experiments is the goal of research now under way on the components of such boards. The information is needed for shipping fruits, vegetables, and other foodstuffs with adequate protection from freezing or, conversely, to keep them in a frozen state during transit. A pilot cooperative study demonstrated the value of new research methods for establishing the thermal properties of three corrugated board constructions. These methods are being employed in the expanded investigation, object of which is to develop criteria for designing containers of known thermal insulating value.

New Tape Closure Patented

A simple tape closure method that securely holds shut the stiff flaps of even triplewall corrugated containers has been invented by an FPL packaging engineer, Clarence A. Jordan. A slot cut into the edges of the lower flaps permits fastening pressure-sensitive tape to the bottom faces of the flaps and passing it up through the slots and between the edges of the outer flaps, so that it can be fastened to their tops. The method is covered by a public use patent.

Sampling Methods for Wood Properties

Advances in statistics, particularly that branch devoted to sampling methods and probability estimation, have provided new and more sophisticated methods of determining the reliability of property determinations of materials based on test data obtained from samples. In particular, they make possible more precise estimates of strength and related properties. Three methods are now available for sampling species populations to determine the mechanical properties of a given kind of wood.

The establishment of a mechanical property is based either on a determination of the average value of that property for a given species or on a near-minimum value — the so-called lower exclusion limit. The reliability of any such determination depends on the precision of the estimate, since the true value can only be approximated. It becomes useful, therefore, to establish a confidence interval within which the true value can be expected to occur. A sampling method that yields a confidence interval obviously is much more useful than one that does not.

The three sampling methods available are:

1. **Cruciform sampling.** This is the method originally used to collect tree samples on which most

Extreme taper and buttressing of dawn redwood logs received at U.S. Forest Products Laboratory is demonstrated by technician George M. Paulson, who balanced one log atop another. M 133 620

mechanical properties of commercial species have been based. It is based entirely on subjective decisions as to what to collect and where. There is no way to measure precision of estimate. Nevertheless, a substantial amount of useful information has been obtained with it, and it is probably the fastest method available for sampling. Laboratory costs are relatively high.

2. **Density survey sampling.** This method involves systematic sampling of a large number of trees for specific gravity, and relating the specific gravity to mechanical properties. The precision of estimate for average properties can be evaluated, but there are no known procedures for calculating precision of estimate associated with lower exclusion limits. The method is particularly useful where property-specific gravity relationships are available before the sampling is begun.

3. **Random sampling.** This method involves sampling a species with probability of specimen selection proportional to timber volume. It is objective and practically unencumbered by assumptions. Precisions of estimate can be simply calculated for both exclusion limit and average. The method supplies a rationale for weighing cost of additional sampling against value to be gained in terms of precision of estimate. Laboratory costs are relatively low, field costs relatively high.

A cost analysis for the cruciform and random sampling methods shows that the total cost of obtaining numerical results from one tree for the five most important tests (static bending, compression parallel and perpendicular to grain, shear, and hardness) is 25 percent greater with cruciform than with random sampling.

The random sampling technique was used in 1967 to obtain data for spruce pine, one of the less well-known southern pines. With some modifications, the technique will also be used for Engelmann spruce and other species.

Automated Data Processing

Measurement of strength and related properties of wood and wood-base materials requires successive observations of dimensions, loads, deformation, and time as testing proceeds, and these observations must be tabulated, recorded, computed, and analyzed. The whole process appears susceptible to automation with modern computerized techniques. A digital acquisition system is being developed that automatically, with a potentially great saving in manpower, converts the analog signals of load and deformation supplied by a universal-type testing machine to digital signals on a punched tape. The digital signals can be converted for processing by the Laboratory's computer. Personnel are being trained to operate the equipment and program the data for the computer.

Dawn Redwoods Eclipsed

The so-called 'dawn redwoods,' which grew widely in forests many millions of years ago, apparently do not have much of a future. Not as timber for man's use, at least.

The wood of this species discovered living in a remote Chinese valley in 1941 and before then known only from fossils perhaps 80 million years old, is too lightweight, weak, limber, and soft to be very useful, FPL evaluations reveal. Too many modern species are better.

The properties judgements were based on wood of specimen logs shipped from the National Arboretum in Washington, D.C., where ornamental trees had been grown from seed obtained from China.

The species is known botanically is *Metasequoia glyptostroboides*. Botanists disagree on whether it is an ancestor of the California redwoods, especially *Sequoia sempervirens*, the Coast redwood. Its wood closely resembles that of California redwood in color and cell structure, and the cones and seeds also are like those of true sequoia. Fossil evidence, however, indicates that the sequoias came first in geologic time, some 100 to 150 million years ago.

WOOD FIBER PRODUCTS RESEARCH

Despite unavoidable interruptions necessitated by the task of moving all fiber products research equipment — from laboratory benches and beakers to digesters, the paper machine, and other pilot plant machinery — into the new buildings completed during the year, research in wood fiber products made substantial progress during 1967. Among developments were these:

1. Improvements in the quality of hardwood pulps for printing papers, achieved by successful fibrillation of troublesome vessel elements that create so-called 'picking' problems in printing.

2. Successful hot-washing of semichemically digested chips while still in the digester, without impairing pulp strength.

3. Production of good printing papers from largely "juvenile" wood of young southern pine trees thinned from plantations.

4. Discovery that, in small amounts, the filler clay used in many grades of paper to improve surface properties, but with weakening effects on sheet strength, can be strongly bonded to pulp fibers.

5. Experimental demonstration that the extent of hydrogen bonding in paper can be closely estimated by electrical conductivity measurements.

6. Evidence that edgewise compressive strength of paper can be increased greatly when the sheet is under simultaneous transverse tensile stress.

Chip Washing in Digester

In-digester washing of semichemically pulped chips to remove most of the pulping liquor has been shown, in pilot-scale experiments, to be feasible. Up to 80 percent of the chemical was removed during a 10- to 20-minute wash at or near digestion temperatures.

In-digester washing has great promise because it reduces the amount of processing otherwise necessary and permits more economical and faster removal of pulping chemical for reuse. This not only reduces pulping costs and shortens overall process time, but helps curtail pollution.

This method of removing chemical while digestion of the wood is still in progress is a commercial success in the kraft process, in which the chips are much more completely pulped than in semichemical pulping. The processing equipment used for washing kraft pulp in the digester is not practical, however, for semichemically softened chips, which must be mechanically fiberized after digestion.

The FPL experiments were conducted to explore various possibilities for in-digester washing. The digestion was found to continue through part of the washing process. Pulp strength was not impaired.

Horizontal digesters were used in the experiments. This mitigated one of the problems now blocking commercial in-digester washing of cooked semichemical pulp chips. This problem derives from the tendency of the chips to pack in a vertical digester of the type used in a kraft pulping. Packing, of course, makes it difficult to circulate wash water through the charge of chips. Results of the experiments are expected to be useful in designing commercial-scale equipment.

Species Effect on Chip Impregnation

Differences between wood species in penetrability by pulping chemicals are under investigation, because digestion time is substantially lengthened if mixtures of species include woods hard to impregnate. These differences are becoming more important as greater emphasis is placed on short cooking time and continuous pulping. The FPL research is aimed at finding practical techniques for improving pulp liquor penetration into dense and impermeable woods.

The difference between hardwoods was brought out in impregnation experiments with white birch and white oak. Chemical distribution within the impregnated chips was determined by quick-freezing and microsectioning the chips and analyzing the sections for chemical content.

Neutral sulfite cooking liquor readily penetrated

Technician Harland E. Wallace empties pulped chips from small digester.
M 134 434 No. 6

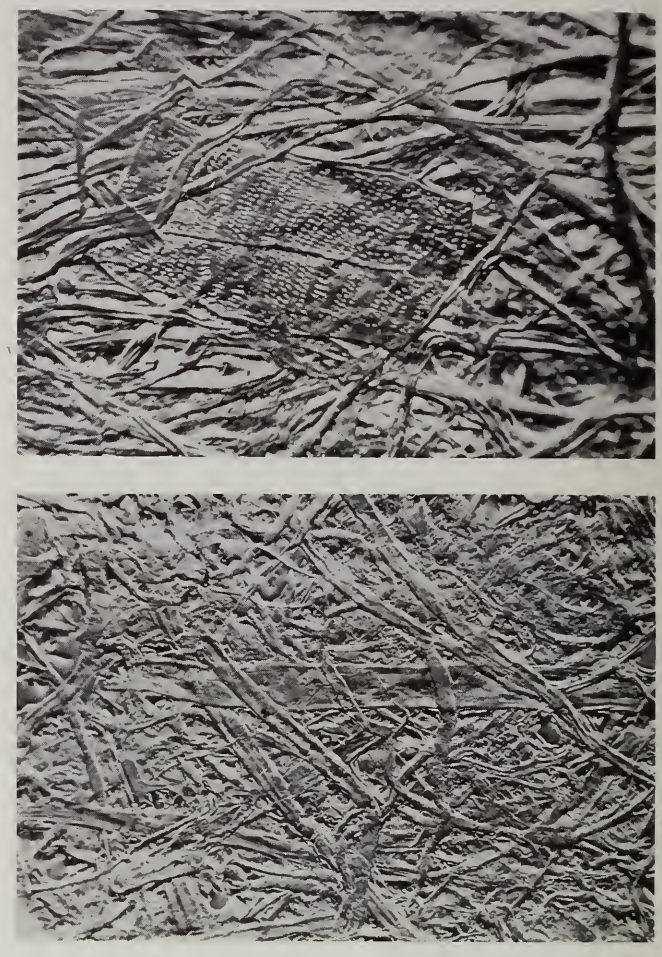
to the center of white birch chips in 15 minutes at 170° C. White oak, on the other hand, was so resistant that digestion schedules would have to be modified if this species were included in a hardwood mix. The resistance to penetration was attributed to the tyloses present in white oak cell cavities, which have long made this species a favorite for casks and barrels for liquids.

The white birch absorbed twice as much sodium sulfite liquor as magnesium sulfite liquor. This was ascribed to differences in cation and solubility between the two liquors.

Experiments are being continued to find a way to improve penetrability of high-density, impermeable species, such as the oaks, to improve their usefulness as pulp species.

Pulping Chemistry

To reduce loss of usable wood substances — notably polysaccharides—that are removed along with lignin during chemical pulping, the chemistry of kraft pulping is under intensive study. Up to 30 percent of available polysaccharide is lost with current commercial processes. Polysulfide pulping, as experimentally developed at FPL during recent years, increases yields of kraft-type pulp substantially by stabilizing the polysaccharides against alkaline degradation. This stabilization is known to be the result of oxidation at the end of the polymer chain, which yields a variety of acid end units. It



Through the microscope, fiber "picking" on a printing press is seen to be due to large vessel elements so weakly bonded to surrounding fibers that ink easily picks them off. In upper photo, a large flat vessel element is clearly visible on the surface of a sheet made of conventionally refined kraft pulp high in oak fiber content. Lower photo shows surface of paper made of a kraft pulp similarly high in oak content but specially refined to fibrillate vessel elements.
M 134 555

has long been assumed that these end units are metasaccharinic acids. Qualitative analysis has now shown, however, that other acid groups are also formed.

Research is being continued to ascertain the comparative stabilizing effectiveness of the different acids. In this work, model compounds of known chemical structure, such as disaccharides with a known acid end-group, are being used. From this research it is hoped to develop other oxidation reactions suitable for stabilizing wood polysaccharides toward alkali, and thereby develop more efficient pulping processes.

Hardwood Printing Papers

Pulps made from hardwoods, especially the abundant oaks, contain broad fibrous vessel elements that

In experiment to study bonding of mineral additives to pulp fibers, Dr. Hans Schott adds suspension of clay to pulp.
M 134 434 No. 9

do not become properly fiberized during conventional refining. As a result, these vessel elements do not bond firmly with other fibers in the paper sheet and can be pulled off the sheet by printing inks. This so-called 'picking' has put printing papers made of hardwoods, especially oaks, in bad repute with printers. As demonstrated by FPL some years ago, these vessel elements can be screened out, but at the cost of substantial amounts of pulp fiber.

Further investigation has now shown that vessel elements can be fiberized well enough to greatly reduce picking problems in a refiner that has a gyratory action. Papers made at FPL from pulp so refined showed much greater resistance to picking than control papers made from conventionally refined pulps of the same high oak content. The improvement was shown to be due to much better internal bonding strength of the paper. The development is expected to encourage the widely available and plentiful oaks in hardwood printing papers and to reduce, or perhaps eliminate entirely, the need for sizing the papers with expensive chemicals to prevent picking.

Southern Pine Printing Papers

Kraft pulps made from young southern pines removed from a stand to stimulate growth of remaining trees can be made into papers and paperboards of good printing quality, FPL experiments demonstrated. The papers were better formed and had smoother surfaces than papers made from the wood of mature southern pine.

The superior printing quality of the papers and boards was due to the so-called juvenile wood in the sapling trees. This wood has softer, more flexible fibers than mature southern pine. Papers and linerboards had strength properties that were, with the exception of tearing strength, as good as, or better than, those made from mature wood.

The pulp made from thinnings was also made into facial tissue that was superior in softness and absorbency to tissue made from kraft pulps of mature southern pine.

Throughout the South, some 13 million acres of southern pine plantations are being grown. Each year another ¾ million acres are planted. The Forest Service estimates that the potential annual supply of southern pine thinnings is about 3 million cords — almost 10 percent of the current annual pulpwood needs of southern mills. In addition, there are millions of acres of natural forests in need of thinning.

Bonding Filler Clay to Paper

More than 2 million tons of additives are used each year by the paper industry to improve surface smoothness, reduce ink absorbency, increase opacity, or add wet strength to various kinds of papers. Among such additives are sizing agents, pigments, and resins. Additives thus contribute greatly to the versatility of paper and enhance its competitive position in many markets.

Among fillers commonly used are low-cost clays. Their use is not all gain, however. These mineral fillers lower internal sizing and usually impair those strength properties which are dependent primarily on fiber-to-fiber bonding. Such papers generally contain 4 to 15 percent by weight of clay pigment.

Experiments are under way to establish the cause of this strength reduction. Object of the work is to learn whether the sheet is weakened because clay does not bond as strongly to cellulose as does cellulose to itself, or because the clay particles reduce the bonded area of cellulose.

The strength of clay bonds to cellulose was evaluated with a bentonite clay applied to two highly purified pulps, cotton linters and southern pine kraft. The clay was found to break up in water into plates or lamellas only 10 to 40 angstroms thick, which formed coherent films when dried. This thin film of clay was strongly retained by pulp fibers, covering a large proportion of their surface. Samples of the clay-filled pulps still retained 0.6 percent of clay after extensive washing.

Handsheets made of beaten pulp without clay were compared with sheets containing 0.6 percent

of clay and found to have nearly the same strength and optically bonded area. This demonstrated that the clay adhered to the fibers about as strongly as the fibers did to one another in the fillerless sheet. This is believed to be due to the fact that the surface of the clay lamellas is covered with oxygen ions that act as hydrogen bond acceptors for the hydroxyl groups of the cellulose molecules in the fiber surface and induce dipoles in the bonds of the atoms comprising the cellulose molecule.

Measuring Fiber Bonding

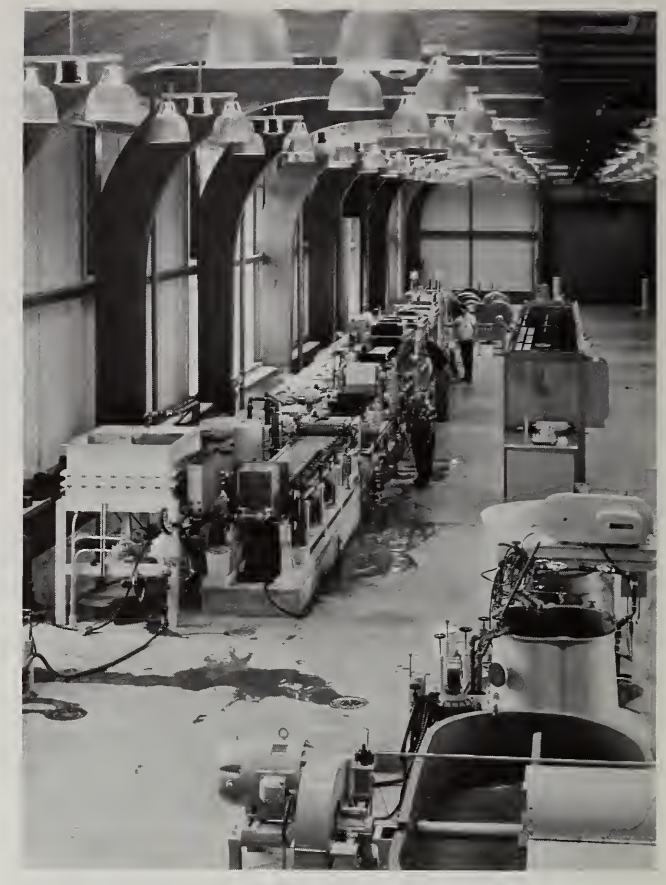
The strength of paper is largely due to the hydrogen bonds formed between fibers. There is, however, no known method of directly measuring either the number of such bonds or their strength. FPL research on the electrical conductivity of paper has now reached the stage where there is strong promise of developing a method of measuring the extent of bond formation in a given specimen as a percentage of the total number of bonds possible in the specimen.

Hydrogen bond formation is strongly affected by various processing treatments, notably pulp refining and the various drying and pressing operations performed by a paper machine. A method of measuring the extent of hydrogen bond formation as affected by these processing steps is therefore of fundamental importance in papermaking technology.

The new FPL studies of electrical conductivity have demonstrated that conductivity is directly related to the number of hydrogen bonds in a handsheet specimen of given size. Conductivity is dependent on two things, the number of bonds, and the amount of electrically charged particles in a sheet. In order to get an approximation of the number of bonds, the amount of such charged particles, called ions, must be known.

Small quantities of ions are present in the sheet as a result of molecular breakdown of water, which leads to the formation of hydrogen and hydroxyl ions. But it is impossible to count the number present in a specimen. So known quantities of other ions are added to each sheet by soaking it in a solution of potassium chloride, then drying it. The treated sheet contains so many potassium and chloride ions that the naturally formed hydrogen and hydroxyl ions can be ignored in conductivity measurements, each specimen can be assumed to have an equal number of ions, and the number of fiber-to-fiber bonds becomes the controlling factor.

Fiber bonding can be increased in various ways. One method, resembling passage of the sheet through press rolls on a paper machine, is to place the sheet between wet blotters and compress it. This increases the number of hydrogen bonds by bringing the fibers closer together—often close enough so that a molecular layer of water adsorbed to the fiber acts as a link between cellulose chain hydroxyls that would otherwise be too far apart to be bonded. When the sheet is dried to its original moisture content, a great increase in conductivity can be measured.



New sections were added to the FPL paper machine when it was installed in roomier quarters of the new pilot plant. A few shakedown runs soon put it back in business, more versatile than ever.

M 134 576

Such bonds, it was found, are extremely sensitive to moisture content changes in the relative humidity range of 30 to 65 percent. For example, in a sheet at 5 percent moisture content — that is, in equilibrium with 30 percent atmospheric relative humidity — about half of the cellulose hydroxyl adsorption sites are occupied by water molecules. If the sheet is compressed to twice its original density and then dried again to 5 percent, conductivity is increased 8.5 times. If the specimen was originally at 8 percent moisture content, its conductivity after wet pressure and redrying is increased 33 times. The logical conclusion is that, in the specimen at 5 percent, the number of fiber-to-fiber bonds was increased 8.5 times; and in the sheet at 8 percent, the number of bonds was increased 33 times.

Conductivity measurements are made at extremely low amperages — on the order of 0.00000001 am-

Ends of pulp specimen are mounted in mercury electrodes for conductivity experiments to measure extent of hydrogen and hydroxyl bonding between fibers.

M 134 367 No. 6

pere. Specimen size is, of course, equally as important as the current input in calculating conductivity as a measure of hydrogen bonding.

Paper Strength Properties

An intriguing discovery, for which no practical application has yet been devised, is the phenomenon that, when a paper sheet is under transverse tensile stress, its edgewise compressive strength is greatly increased. Experiments indicate that compressive strength can be virtually doubled by exerting a tensile force in this manner.

The finding has potential significance for fiberboard container design where compressive strength is important, as for carrying stacking loads in a warehouse. If a tensile stress can be induced in the liners of corrugated containerboard, it appears possible to exploit this finding either by making boxes of greater compressive strength with a given amount of pulp fiber or using less fiber in boxes designed for a given compressive strength. The enormous quantities of wood fiber used for containerboard make either possibility intriguing from an economic standpoint.

SOLID WOOD PRODUCTS RESEARCH

The broad object of research on solid wood products at FPL continues to be more effective, and thus more economical, wood utilization through improvement in the processing and protection of wood in solid form and through the development of new concepts for the use of wood in solid form. Such a program may be expected to:

1. Decrease the costs and increase the quality of the finished product.
2. Increase the utility of material of marginal quality.
3. Reduce the annual requirement for standing timber needed for a variety of uses by increasing the service life of wood products, which will in turn reduce the annual cost to the user.
4. Stimulate the use of wood in construction and other applications.

In approaching this objective, both applied and fundamental research are involved. At this point in time, substantial effort is going into fundamental aspects in order to substantially supplement the return from empirical research. For example, over the years tremendous effort has gone into improving seasoning procedures. We are now taking a closer look at how and why moisture moves through wood to see if clues to new or improved seasoning procedures can be developed. Likewise, much effort in the past has been put into the evaluation of various chemical compounds for improving the fire behavior of wood. We are now engaged in a strenuous effort to seek out the mechanisms by which pyrolysis and combustion of wood and its components occur to see if changes in the mechanisms might be made by chemical or other means to improve more effectively the fire behavior of wood. Again, the lack of a long-lasting finish on wood has long been a problem and has in fact led to a substantial loss in the market for wood siding. This has been especially true of so-called natural finishes. We are devoting considerable effort to searching out the physical and chemical factors involved in the failures of finishes, again with the idea that such knowledge will lead to a better finish system.

This emphasis on basic research does not mean that applied research is being neglected. On the contrary, the following paragraphs deal with both types of work in progress.

Thiamine Depletion

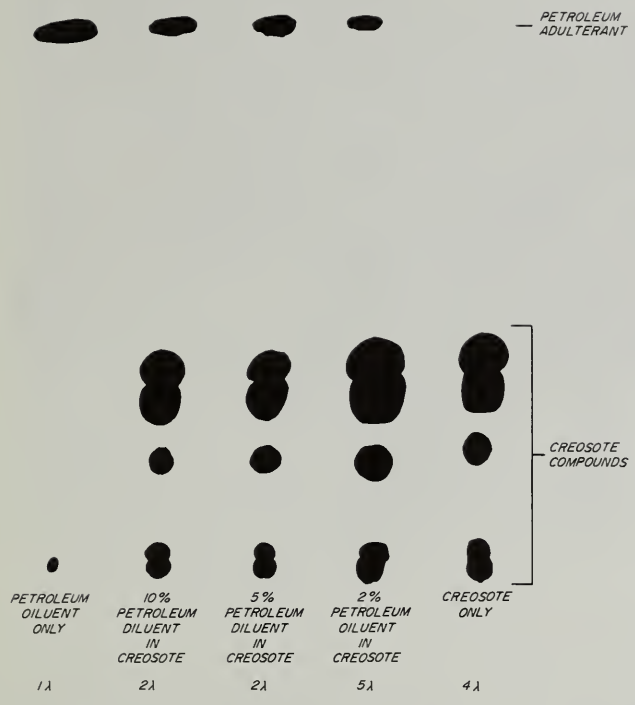
The effectiveness of the thiamine depletion method for protecting wood against fungi has been previously reported (see 1966 Annual Report). There has been concern that the thiamine, carried by dust, might be reintroduced. Now, however, we have good evidence that this is unlikely, at least in quantities sufficient to make the treatment ineffective.

Southern pine lumber that has been dethiaminized and exposed above ground for 8 years in the South remains in generally excellent condition even without a protective coating. We have, therefore, increasing potential for savings to homeowners and others through availability of well-protected, clean, paintable lumber. The extra cost is expected to be nominal, and the potential savings could run to millions of dollars annually.

Preservative Quality Control

Research has uncovered a technique that may provide for the first time an adequately simple and reliable means of detecting significant petroleum oil adulteration of creosote. For marine service, it is highly important that creosote be free of such adulteration. The method utilizes thin-layer chromatography, whereby spots of petroleum oil show up distinctly separate from those of the creosote components. Research on the method is continuing to establish whether it can contribute to quality control of commercial creosote.

A major obstacle to dependable quality control of preservative treatment has been the lack of suitable, practicable means of checking on the adequacy of treatment by examining the treated products. Some of the Laboratory's efforts to overcome this obstacle have paid returns in the form of a number of results-type standards in the current federal specification for pressure treatment. Additional en-



Thin-layer chromatograph shows clear evidence of a petroleum adulterant (uppermost spots) even when present in as small an amount as 2 percent.
M 133 804

Laying experimental deck seal on Lander's Fork Bridge, Helena National Forest.
M 133 874

couraging progress in meeting the need was made during the year in two ways: (1) Through the development of detailed data on the distribution of representative major preservatives obtained by conventional pressure treatment, and (2) through trials of X-ray emission spectography for rapid, precise evaluations of pentachlorophenol and salts treatments.

Prolonging Bridge Life

The interest of the Forest Service in finding means of prolonging the service life of its bridges was served by assigning a pathologist practically full time to the problem. Decay hazards are being studied in 17 bridges. A major hazard to the larger, permanent-type bridges appears to be water entry around deck fasteners, causing the upper laminate of the glue-laminated stringers to get wet.

To cope with this hazard, continued emphasis was placed on experiments with deck seals. A suitable sealing compound hopefully may go far toward economically protecting both the bridge deck and the stringers. The potential for a successful deck seal still appears large. The possibility of designing a sealable, wood-decked native timber bridge was explored with engineers. This would be an alternative to the rock deck now widely used in Alaska.

The supplementary protective measure consisting of bituminous coatings over localized places subjected to rain wetting continues to look promising. Places needing such protection — if it proves adequate — are weather checks in wood, end grain of timbers, and areas around metal fasteners. Experimental coatings now 2 and 3 years old appear to have suffered no serious degradation of sealing properties.

Deterioration of Stored Chips

Microbiological studies of stored pulpwood chips in the South and Northeast were carried to terminal phases. The data gathered included identification of the principal micro-organisms causing damage and determinations of certain of their physiological characteristics and capacity to degrade wood. A number of thermophilic and thermotolerant species of fungi were discovered in Northeastern chip piles. Their presence readily accounts for the comparatively high temperatures (+ 50° C.) measured in the experimental pile and the considerable gravity losses biologically produced in zones where the higher temperatures prevailed.

The value of stored chips in the United States is estimated to be as much as a billion dollars, and losses of wood substance and quality amount to several million dollars. Consequently there is urgent need of economical means of preventing such losses if possible.

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An isolated Canadian termite infestation in 1967 became the target of FPL and Canadian scientists in an experiment designed to test the efficacy of a new insecticide-bait as a means of exterminating the colony.

1. Dr. Glenn Esenther, left, FPL entomologist, and David Gray, Canadian Forest Products Laboratory entomologist, inspect stakes treated with poison bait to attract termites foraging in the earth.

2. Dr. Esenther examines a stake "barricade" installed to protect a building from termite attack. Poison-bait treated stakes are intended to divert approaching termites and destroy them.

3. Termites are removed from wood stake for study in laboratory.

4. Termites cluster on this wood stake treated with attractant discovered by Dr. Esenther and buried in soil.

M 133 345 Nos. 2, 3, 8, 10

Treatability of Redwood

Redwood is a species with quite high natural moisture content—often ranging up to 200 percent —and is unusually slow to dry. Since this species is used in high volume, the question of interference of the high moisture content with treatability has great practical significance.

Treatability of redwood with a water-based preservative over a wide range of moisture content was investigated. A substantial moisture effect was found; there was marked reduction in both penetration and retention as moisture content increased. The results indicate that a moisture content not exceeding the fiber saturation point is necessary for acceptable preservative uptake and penetration.

Termite Attractant-Insecticide

In collaboration with th Canadian Forest Products Laboratory at Ottawa, 16 experimental plots were installed in an isolated infestation in Ontario to determine the termite-eradicating potential of a combination termite-attractant and insecticide under development at FPL. The particular aim of the Canadian experiment is to ascertain whether the attractant-insecticide can eradicate termite populations in such localized pockets of infestation. Evidence of termite reduction on the experimental plots 1 year after their establishment was substantial.

Environmental Research

FPL environmental research includes the development and evaluation of a sun-following exposure rack (see 1966 Annual Report) and studies of moisture and temperature conditions in an exposure building. A new 300-channel data system has been installed, permitting a major expansion of the amount of information that can be obtained.

A nationwide study of the moisture content in laminated beams being carried out by the Southeastern, Rocky Mountain, and Pacific Northwest Stations in cooperation with FPL has been under way for over a year. Indications are that the normal range of moisture content of beams in use is from 7 to 12 percent, depending on season of year and climate. This range is not as wide as expected. Of course, there are occasional examples of higher moisture content, but these can usually be traced to liquid water entry, not high relative humidity or condensation.

A preliminary evaluation is under way on a new type of wood siding. In theory it is the essence of

Technicians Paul Evans and Albert Higgins inspect installation of Solar-groove siding they invented.
M 134 153 No. 4

simplicity—to have reflecting surfaces face the sun in summer and reflect heat away from and help cool the house, and to have absorbing surfaces face the sun in winter to absorb heat in the siding and keep its temperature higher and reduce heating costs. The siding surface consists of a series of V-shaped grooves machined in such a manner that the bottom surface of the groove faces the sun in summer and the upper surface of the groove faces the sun in winter. The bottom of the groove is painted with a reflecting coating and the upper surface with an absorbing coating.

Specimens of the siding, called solar-groove siding, were mounted on the south wall of a building along with controls painted all white and all black. Temperatures of the backs of siding specimens were recorded.

Representative temperatures at solar noon on a warm September day were 89° F. for the all-white siding, 93° F. for the solar-groove siding, and 118° F. for the black siding. Similar data taken early in December show that the temperature on the back of the white siding was 52° F., on the back of the special siding 76° F., and on the back on the black siding 81° F. The solar-groove siding thus functioned more like high-reflectance white siding under summer conditions and more like high-absorption black siding under winter conditions.

The solar-groove siding was spray-painted. It is believed that a special holder for a spray can will permit repainting without a great amount of extra effort.

Further study is under way of groove size and angle as these relate to production problems, refinishing, and appearance. Also being evaluated are such factors as potential dollars-and-cents savings in heating and air conditioning costs, determination of the number of situations in which this siding might remove the need for central heating and/or air conditioning, and consumer acceptance.

Gluing and Glued Products

There is currently much interest in acid-catalyzed adhesives for production of overlaid wood products. This has brought on a definite need for durability tests that can evaluate the effects of the acid constituents on predicted life expectancy of bonded wood products.

Such effects were noted during the accelerated aging of adhesives, using rate process methods of analysis while exposing bonded specimens to dry heat (see 1965 Annual Report). These methods established that dry heat reduces shear strength of plywood specimens in two stages. The first stage takes place rapidly and is difficult to measure as a rate process. The second stage proceeds more slowly and is readily measured by our current techniques. An estimate of the extent of the strength loss occurring in the initial stage can be obtained by extrapolating the second-stage rate equations to zero time and comparing the strength value so obtained with the original control values.

Strength loss was found to be independent of the temperature of heating. The observations suggest that the available acidity degraded the wood adjacent to the glueline. Also, the acidity appeared to be consumed in the process.

These results illustrate how accelerated aging by rate-process analysis can add appreciably to our knowledge of adhesive behavior in service environments. This brings us one step closer to the day when such laboratory methods can be used to predict the service life of an adhesive-bonded wood product with accuracy.

Rate-process methods of analysis showed that moisture is the major factor determining the durability of urea-resin-bonded joints. Elevated temperatures accelerate the deleterious action of moisture on the urea resin.

End-Grain Bonding

Such conventional adhesives as polyvinyl acetate, urea resin, and resorcinol resin form very weak butt joints in white pine, their tensile strength falling in the range of 1,700 to 2,900 pounds per square inch. These adhesives shrink as they lose water while drying and curing. This shrinkage sets up internal stresses in the glueline which effectively reduce the tensile strength of the joints. Epoxy resins that do not contain solvents and consequently shrink but little during the cure yielded tensile strengths of 3,100 to 4,400 pounds per square inch, but this

is still less than 50 percent of the strength of the clear wood. When the specimens broke, it was always within the adhesive close to the wood-adhesive interface. It was obvious that a weak boundary layer developed at this location in the adhesive during the bonding operation. It was theorized that the development of this weak boundary layer might be prevented if the cure rate of the adhesive could be speeded up.

Cure was speeded up by applying a highly reactive catalyst to the end surfaces of wood, and also by heating the wood before applying an epoxy resin to the bonding surface. Tensile strengths as high as 7,500 pounds per square inch were achieved by both methods. This interesting phenomenon is as yet imperfectly understood and further study is needed to optimize this increased effectiveness of an adhesive.

The original intent of this research was to develop more effective finger joints, which necessarily expose a certain amount of end grain at the tips of the fingers. This represents a source of stress concentration. A bonding system which would assure high strength at the tips of the fingers should add markedly to the overall strength of the joint. The success achieved so far, however, also raises hope of making strong and useful butt joints.

Experimental particleboard comes out of hot press.
M 134 424 No. 10

Particleboard Production, Properties

Acquisition of a new press has made possible a broadened attack on problems in the manufacture of particleboard. Reduction of pressing time, which has obvious advantages, is one of the first being explored. An exploratory study of the effect of rate of closure has shown that Douglas-fir flake boards made with a short press-closing time, 1½ minutes or less, had the highest modulus of rupture and internal bond values. Failures in tension were restricted to the center section of ½-inch board specimens. A fast close of 18 seconds produced boards of moderately high modulus of rupture but low tensile strength perpendicular to the surface.

Exploratory work is continuing on fabrication of particleboards made with urea-, phenol-, and melamine-formaldehyde resins and a number of representative fire-retardant treatments. Several combinations of these additives and binder resins were found to provide the required protection at practical concentrations, though the boards were somewhat weakened by the interference of chemicals with curing properties of the resins. Fire-retardant-treated boards with urea binders were particularly deficient in strength. Phenol and melamine resins were generally less affected by the fire-retardant chemicals. It appears that because of the catalytic effect of many of the fire retardants, the rapid curing of the resin near the center of the board before the press is actually closed reduces internal bond strength. The performance of the surface levels of these boards remained satisfactory, indicating that an effective binding action is taking place.

Exploratory work on steam stabilization of particleboards was completed. Apparatus was designed for steaming a stack of particleboards at temperatures up to 360° F., with or without restraint against swelling in thickness. This greatly reduced "springback," which is the irreversible swelling that takes place when the board is soaked the first time.

A shadowline technique has been used at FPL to record, and roughly measure, the surface imperfections of particleboards and other panel products. The shadows of two tightly stretched wires (0.025 inch in diameter, 1/10 inch apart) are projected at a 1 in 5 slope on the surface of the board. The shadows of these wires are photographed from above. This gives a measure of the vertical distortions, and the difference in thickness between two panels laid on a common base can be determined from the displacement of the shadows.

A portable shadowline apparatus permits the evaluation of a 5- by 5-inch square area in any position. This apparatus can be used, without any services such as electrical connections, to evaluate siding on a house, soffits, facia boards, etc., without regard to lighting conditions.

A thick roof-deck type of particleboard made with a pulp-chip core and flake facings has been evaluated for deflection under long-time loading, dimensional stability, and changes in form and size after aging. Results indicate that it may be expected to serve well as roof decking over spans of 48 inches at a design load of 30 pounds per square foot. The mechanical properties, including resistance to sag, are such that better performance may be expected from this material than from one commonly accepted and made from fiberboard.

Examining a piece of honeycombed white oak are, left, S. N. Sharma, Research Officer, Wood Seasoning Branch, Forest Research Institute and College, Dehra Dun, India, and John M. McMillen, FPL wood seasoning specialist. Sharma visited FPL in August, 1967, while returning to India after studying on an FAO fellowship at North Carolina State University. He is doing research at the India laboratory on the causes and alleviation of refractoriness of Indian woods under a Public Law 480 grant made by the U.S. Department of Agriculture from funds obtained by sale of surplus agricultural crops.

M 133 294 No. 4

Wood Drying

Checking and honeycombing are two of the most common drying defects. During the past year, new light has been shed on their causes, renewing hope that more efficient control may be possible in a few years.

A study of drying stresses in 2-inch ponderosa pine gave new insight into moisture movement in softwoods. Instead of a uniform parabolic moisture gradient during drying, a three-dimensional hodgepodge of moisture content levels was frequently found. This makes the future research job more complex—a uniform moisture gradient is much easier to study—but also helps to explain some of the erratic results reported by industry.

The second research effort that adds a missing piece to the drying defect jig-saw puzzle concerns the influence of stresses on moisture content. It has been known for a long time that drying stresses are caused by moisture content gradients. We now know that stresses cause the wood to gain or lose moisture. This effect, which is thermodynamically predictable, has now been experimentally verified. While its precise influence on the moisture gradient during drying remains to be evaluated, it appears likely that this is another factor that will have to be dealt with in the development of procedures for the control of checks and honeycomb.

New Approaches to Old Problems

New research approaches to two major drying problems have been initiated. These problems are control of color changes and evaluation of solar-drying processes as compared to other drying processes.

Color changes caused during drying are controlled on a hit-or-miss basis. The constantly changing nature of the industry and the forest inventory results in recurring color problems. In the hardwood industry, these color changes are often minor disasters, entire kiln charges being rejected because of poor color. In a new approach the biochemistry of color changes during drying is being studied with the object of finding ways to manipulate drying processes for control of color. Some exploratory research has already led to an improved schedule for the drying of maple to achieve uniformly light-colored sapwood. This is just a first step in this new approach to color problems.

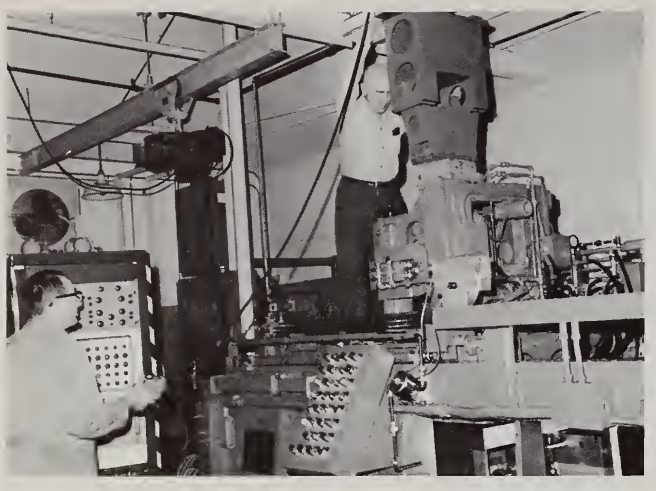
Forest Service research since the middle 1950's has clearly demonstrated that solar energy can be used to dry lumber. A computer program for estimating material and energy balances for various wood drying schedules at different geographical locations has now permitted rapid, inexpensive evaluation of proposed solar drying systems in any climate. This program has been used to evaluate supplemental solar dryer design (solar energy plus fossil fuel) for the drying of oak on a 28-day schedule. The results clearly show that a solar dryer is impractical for this purpose. More general evaluations involving different drying times are under way to answer many questions concerning solar drying, thus eliminating or greatly reducing the need for costly pilot studies in various parts of the country.

Press Drying

Press drying accomplishes in minutes what takes months by air drying and days by kiln drying. Thus it has obvious attractions in terms both of more rapid processing, and probably in costs. The process has been shown to be technically feasible (see 1965 Annual Report).

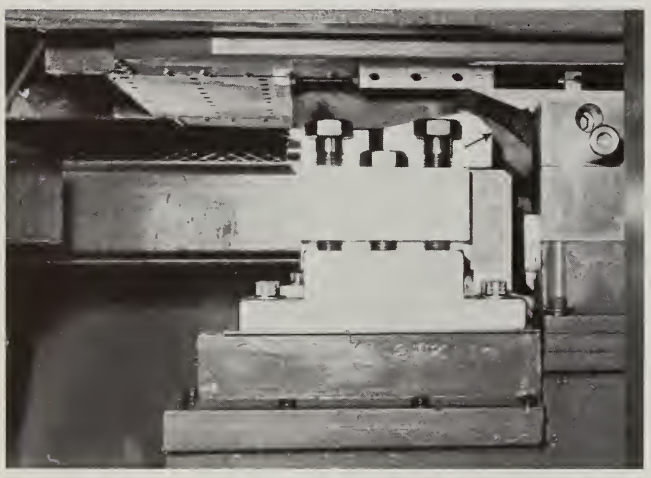
During the past year a number of species were dried between the heated platens of a press. Half-inch material was dried to the 4 to 6 percent moisture content range in 25 to 75 minutes and 1-inch material in 100 to 200 minutes. Not all species dried without degrade; the heartwood of some refractory species was severely checked and honeycombed. All other species tested, however, dried without serious degrade in either heartwood or sapwood.

The economics of the process are not yet known. It is probable that special equipment, rather than a conventional pressing process, will need to be developed to make it fully attractive.



The new experimental cutting machine went into service in 1967. Above, Technicians Harry Panzer and Al Mergen lower a mounted wood flitch into carriage that will carry it across stationary cutting blade at any speed from 1 to 500 feet per minute. Below, cutting knife slices 1-inch-thick piece from flitch. (Checks were formed because machine was stopped in midslice for picture-taking purposes.)

M 134 362 No. 6, 3



Experimental Cutting Machine

An experimental cutting machine especially designed for research on slicing of flitches into pieces much thicker than now produced commercially was installed in May 1967. Experimental work has demonstrated the machine's capacity to position wood flitches and cut 1-inch-thick material. Preliminary evaluation of the slices cut from aspen showed remarkable smoothness. A tendency toward cupping, however, indicated some permanent distortion of the slice. Deep checking and some complete fracturing along the exit edge of the slice indicate the need for complete support of the piece being cut. Research is directed toward determining loads and power requirements, using precision force-measuring transducers.

Machining and Veneer Cutting

The elimination of saw kerf gained by slicing flitches instead of sawing them has considerable economic potential. Production might be increased as much as 20 percent. With an average raw material value of $65 per 1,000 board feet, this represents a saving of $13 per thousand, which, if applied to only 1 to 2 percent of lumber production, could mean a reduction in material costs of $3 to $5 million per year.

A number of slicing experiments have been carried out on a converted milling machine to study the effect of pressure bars of various configurations. In this work, stresses have been imposed to counteract those resulting from the cutting process. For example, as the slice is bent in passing the knife, tensile stresses on the knife side cause checking. A comprehensive stress was exerted opposite to the direction of cutting to counteract the tensile force.

Pressure bars and knives of a number of configurations were used. Included were circular bars, free rolling and driven 10 percent faster than the advance speed of the veneer, and a fixed bar with a supplementary bar behind it to provide restraint. The latter gave somewhat better results than the others.

Recent research has revealed that the quality of southern pine veneer, rotary cut at room temperature with high compression by a roller bar, is directly related to the cutting velocity and moisture content of the wood. When cutting wood with a high moisture content, the load on the roller bar increased with cutting velocity. Veneer quality in turn was affected by loads on the roller bar. When very high loads were observed, the veneer was thin and weak in tension perpendicular to the grain.

These findings are attributed to the fact that water is relatively noncompressible. When wood saturated with water is cut at high velocity, the water does not have time to escape. The higher resistance of the wood to penetration of a knife or pressure bar results in the differences in the quality of veneer produced.

Experiments also indicate that quality of the veneer is related to pressure against the bar during cutting. When the bar is set to stops, as is now done commercially, the pressure varies widely when cutting a single bolt.

From these findings, it appears that a lathe with the pressure bar set to stops, but designed to allow the bar to recede if a given pressure is exceeded, may cut veneer more uniformly.

Natural Finishes for Wood

Some years ago FPL chemists developed a natural finish for exterior use that has come into wide use. This finish, a penetrating stain type, was never

accepted widely in the South because of its susceptibility to mildew. Current studies on modifications provided promising mildew resistance by lowering the linseed oil content, increasing fungicidal content, and substituting a varnish resin for linseed oil. These modifications have reduced the tendency toward mildew and have kept rough-sawn southern pine siding exposed to the warm, humid climate of Mississippi and Florida looking attractive for 2 years.

In the same study on southern pine, a finish consisting of a simple treatment with a water-repellent preservative containing a mercurial fungicide showed complete resistance to mildew and bleached the wood to a beautiful light tan color.

A related research project in cooperation with the National Forest Products Association and the National Paint, Varnish and Lacquer Association is directed toward the development of a treatment for a wood surface that will inhibit degradation of wood by light. Such treatments are needed to expedite the use of very durable clear finishes, based on new polymers such as silicone and polyvinyl fluoride, which transmit ultraviolet light. Such finishes cannot currently be used on wood because the ultraviolet light destroys the wood surface beneath the coating.

Approximately 30 chemical treatments have been studied. The greatest protection against degradation was provided by certain chromate salts, especially copper and lead chromate, and chromate compounds combined with sodium pentachlorophenate and potassium ferricyanide. These inorganic treatments not only provide excellent resistance to photodegradation but also are effective fungicides.

Fire Performance of Wood

FPL fire research covers a wide range—charring rates, mechanism of pyrolysis and combustion, effectiveness of laminating adhesives in resisting fire, effectiveness of basic chemicals in reducing flammability, and the effect of plywood thickness on flammability. Smoke development and the effect of moisture movement and shape of specimen on wood charring are the subject of new studies.

Smoke has long been recognized as a critical hazard in building fires. It obscures vision, leading to panic among occupants seeking to escape from buildings, and obstructs rescue and fire-fighting operations. Some building codes limit the use of wall, ceiling, and interior trim materials on the basis of their potential for smoke development as well as surface flammability.

These restrictions are based on the smoke-density values from the 25-foot tunnel furnace method, the only standard rating test available to the code officials. This method was developed specifically for the purpose of measuring the surface flammability of building materials, and the condition results in a minimum of smoke development. This makes it difficult to differentiate properly between the smoke-development characteristics of materials under the more hazardous conditions. As a smoke-development measure, this method has certain other technical faults; it involves a variable part of the specimen in the test and makes a direct comparison to the obscuration produced by red oak smoke under the minimum condition.

A smoke-density evaluation procedure is now under study that will accurately measure light obscuration as produced from the smoke from wood and wood products under a variety of controlled fire conditions. Aim of this work is to evaluate smoke density separately from flame spread. Identical sample areas will be exposed in each test, and results will be expressed in a specific optical density which is independent of comparison to other materials and can be related to other chamber volumes, lightpath lengths, and sizes of specimen. A chamber and method developed by the National Bureau of Standards is being evaluated for this work.

WOOD QUALITY RESEARCH

Wood quality research under way at FPL ranges from studies of the submicroscopic cellulose microfibrils and lignin crystallites of which wood is comprised to exploring means of automating the sawmill and lumber grading. Among developments in this area of research during 1967 were:

1. Reduction of computer prediction of hard maple cuttings to simplified charts readily usable for estimating yields of a broad range of cutting sizes from lumber of various grades and widths.

2. Experiments with a sonic device for sensing presence of defects in lumber—a basic requirement for automation of lumber grading and processing.

3. Discovery of a method for consistently producing roots and shoots on cultured cambium tissue of aspen that appears to be a promising means of reproducing unlimited numbers of trees of identical genetic potential.

4. Spectrophotometric evaluation of black walnut color tones in physically measurable terms, as part of a study relating walnut quality to growth conditions.

5. Relation of Douglas-fir density to rainfall and elevation on west slope of the Cascade Mountains.

6. Discovery that Grand fir trees infested with aphids produce wood of distinctly inferior quality.

Charts for Estimating Cutting Yields

A long step forward was taken in the simplification of cutting yield estimation from the standard lumber grades of hard maple during 1967, when a pioneering computer analysis was reduced to chart form. The charts eliminate the need for computers to compare the yield potential of the different grades on a cost basis for a given job order for furniture, paneling, or other cuttings. The charts are available in published form, with instructions for use.

Development of the charts was preceded by years of research on 1-inch hard maple boards typifying the ranges of defects and other characteristics of four standard grades of hard maple, from Firsts and Seconds to No. 2 Common. Much of this work was done in cooperation with the North Central

Practicality of the new FPL grade yield charts for hard maple lumber was checked out against regular production runs in this Grand Rapids, Mich., furniture plant among other places. Left to right, David Schumann, FPL technologist, Henry Huber, Michigan State University Extension Specialist in Forest Products, and Dr. George Englerth, FPL technologist in charge of the project, watch operator of a cutoff rig saw cuttings from lumber. (Photo courtesy Grand Rapids, Mich., Press.)
M 133 543

Sound transducers are positioned above and below board submerged in water in experiment to study their effectiveness in scanning board for presence of defects. Operating the controls is Roger Cox, FPL technician.
M 134 543 No. 4

Forest Experiment Station of the Forest Service. The masses of data thus obtained were used to develop a computer program for estimating yields of cuttings of various sizes from the various grades.

Standard hardwood lumber is graded on the basis of the size and number of cuttings that can be sawn from between the knots, mineral streaks, and other defects that occur in hard maple. The lower the grade, of course, the larger and more numerous the defects and the fewer and smaller the cuttings that can be obtained. There are large price differences between grades.

The value of the charts to processors of hard maple lumber derives from the fact that they greatly simplify cost comparisons between grades for a given cutting requirement. Their use is expected to stimulate purchase of the more plentiful and less expensive lower grades. The original object of the study was to develop a computer program for this purpose. When the work was completed however, it was found possible to reduce it to chart form, thereby eliminating the need for costly computer services.

One set of charts is designed to permit estimating yields of cuttings of any specific width from 1½ to 6 inches in lengths ranging from 40 to 70 inches in the FAS and Selects grades, between 20 and 70 inches for No. 1 Common, and between 10 and 40 inches for No. 2 Common hard maple.

Successful conclusion of this study is only the first step in development of charts that will, it is expected, ultimately apply to many other hardwoods as well.

Automated Sawmilling, Grading

The concept of an automated sawmill, with computer controlled decisioning to break down logs most advantageously for yield and lumber quality, is excitingly new and challenging. Already work on one basic part, a sensing device to scan and evaluate boards for defects, is well under way at FPL.

The defect detection device now being experimentally evaluated consists of a pair of transducers, one transmitting and one receiving an ultrasonic signal. The transmitting transducer sends a sound pulse unidirectionally through wood. The receiving transducer is connected to the vertical amplifier of an oscilloscope, which displays the pulse as a curve on its screen for examination.

Some preliminary experiments on a walnut board 2 centimeters thick and a red oak board 3 centimeters thick, both in the green condition, produced erratic results. The erratic results obtained were attributed to the fact that the transmitting transducer was too close to the wood. The transducers were coupled to the wood with petroleum jelly. Subsequent tests were performed under water, with the transducers separated from the board. It was found that sound passes through the water with only slight attenuation and that water makes an excellent sonic couplant to the board. Results were more consistent than in air. Knots were found to increase the velocity of the sound pulse, and holes decreased the pulse amplitude.

Limited results indicate that sound attenuation, as measured by pulse amplitude, can be best employed to detect holes or voids, and that sound velocity can be used to detect knots.

In a companion study, a computer program for grading and scaling hardwood lumber using the standard grading rules of the National Hardwood Lumber Association is being developed. Work was begun by generating a longhand program interpreting mathematically all NHLA rules. Tediously hand tested on about 25 oak boards, the program correctly established the grade of all.

The most important single grade-establishing factor is the potential yield of the board in clear-face cuttings equal to or larger than certain specified minimum sizes. More and smaller cuttings are permitted in the lower grades.

In adapting the longhand program to a computer system, experience gained in the hard maple cutting yield study already described proved highly useful. One problem that developed resulted from the computer's inability to discriminate between

cuttings. That is, it found all possible cuttings in a board with complete disregard to overlapping boundaries. The solution to this problem proved quite complex, especially where three or more cuttings were involved. A method of fractionating the overlap among cuttings was evolved, which solves the overlap problem of an unlimited number of cuttings.

Lodgepole Pine Stud Warp

Strong evidence that the stump end of a butt log influences the occurrence and severity of warp in studs cut from it was obtained in an exploratory sawmilling study of lodgepole pine. The first three feet of the log above the stump were found to be critical with respect to occurrence of warp.

Logs 8 feet long were cut for the study from normal stump height and from 1, 2, and 3 feet above that height. Some logs came from trees that were straight in the first 4 feet above the stump and some from trees with crook or sweep in that area. Severe warp was evident in studs from both straight and crooked trees. Although warp deflection averaged higher in studs cut from crooked trees than in those from straight ones, the differences in the averages for studs from crooked and straight trees were not statistically significant.

Where the tree classes were analyzed independently, average crook differences were significant between positions for the crooked tree class. Average crook in studs from the 2-foot position was more than four times more severe than in studs from the 3-foot position. For the straight trees, the average for the 2-foot position was only slightly more than that for the 3-foot position.

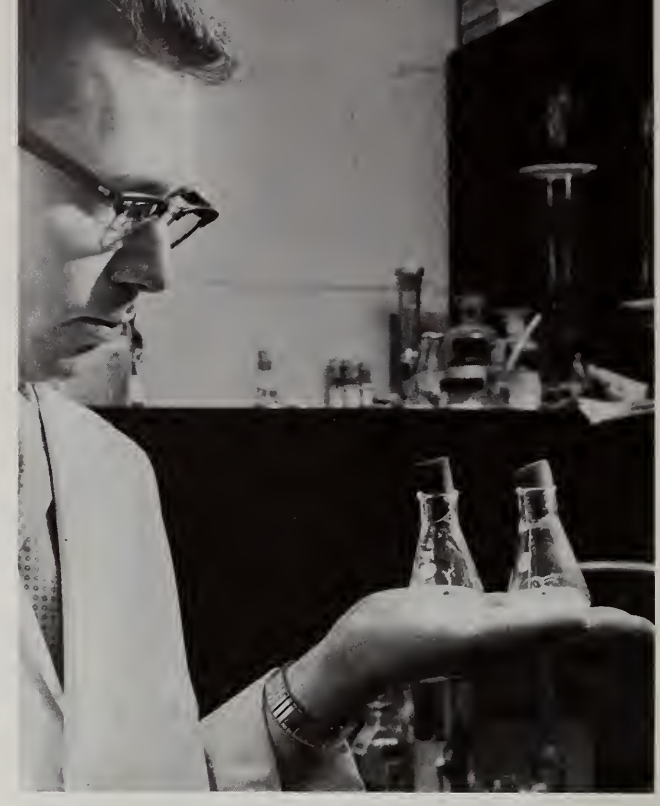
A full-scale study to find ways of sawing small lodgepole pine logs so as to minimize stud warp was carried through the sawing, drying, and milling phases for some 680 logs. Data obtained are being analyzed to make possible a comparison of the different sawing methods used with respect to occurrence of warp.

Controlling Wood Growth for Quality

A highly significant dividend of FPL research on the control of wood quality with nutrients fed living tree tissue was the discovery during 1967 of a method of consistently producing roots or stem shoots on undifferentiated callus — that is, random tissue taken from living trees.

The discovery has great practical significance. It holds promise of developing into a technique for reproducing, in any quantity, superior individual plantlets of identical genetic potential, with great implications for wood quality control in the tree.

Perfection of such a technique hinges on finding a way of growing both roots and stems on the same callus. This is now done on herbaceous plants, which have little or no woody tissue in their stems. FPL research to find such a technique for tree reproduction is under way.



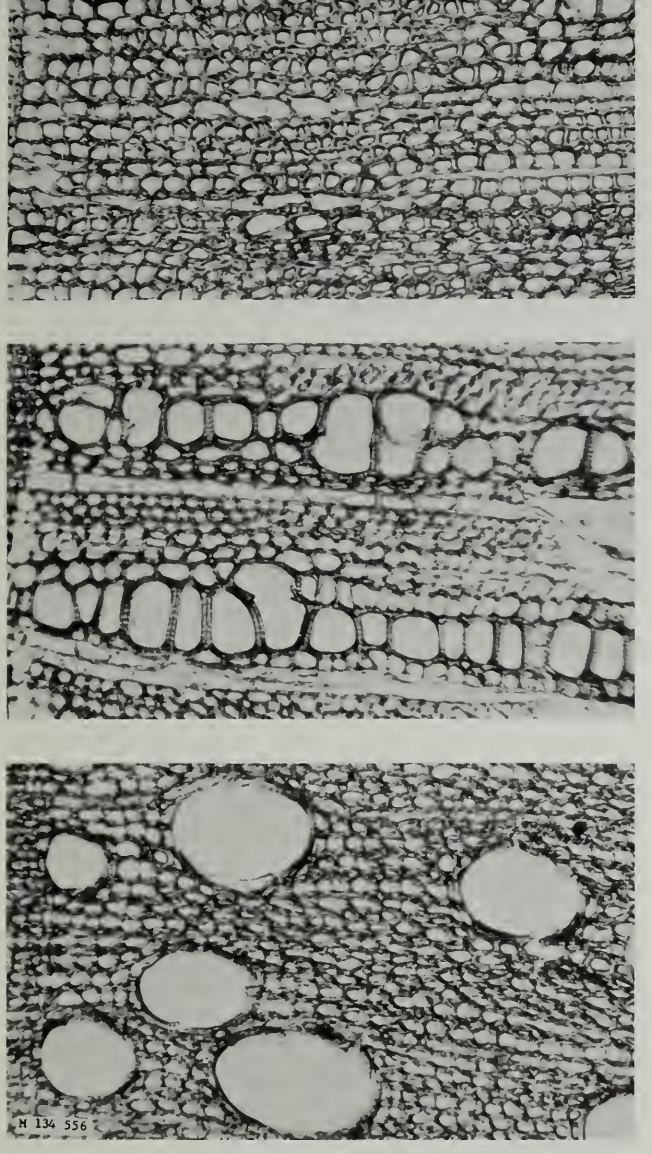
Shoots grown on aspen callus are examined by Technician Adrian Richter.
M 134 558 No. 9

Dr. Karl Wolter, FPL physiologist, discovered the technique for growing either roots or shoots during his research on effects of nutrient nutritional variation on three hardwood species. In this work he has experimented with cambium tissue taken from living stems. The tissue is placed in a nutrient culture containing various vitamins, hormones, inorganics, and energy sources necessary for continued growth of the tissue without the complicating features of crown or roots.

During the 1967 growing season, a long step toward the ultimate goal of controlling the differentiation of specific wood cells by nutrient manipulation was taken. Ash sprouts from which the crowns had been cut were force-fed by injecting them with various nutrient solutions.

Some remarkable effects on wood formation were obtained. There was a high degree of organization of wood tissue elements in the sprouts, as contrasted with the random growth of callus on an identical nutrient culture. High concentrations of specific growth hormones produced a large proportion of fibers to vessels. The vessels were arranged in uniform radial rows and were smaller than vessels in normal ash wood, in which they assume a random arrangement.

The discovery that stems or roots can be grown on undifferentiated callus evolved from the nutrient evaluation studies. It was found that shoots are started by removing a growth hormone called auxin



Transverse sections of ash stems "force fed" with high (upper photo) and low (middle photo) concentrations of growth hormones. Bottom photo shows a cross section of a normal ash stem with large scattered vessels.
M 134 556

from the culture medium and adding an extremely small amount of another hormone, cytokinin (6-benzyl-aminopurine). The inverse condition is necessary to produce roots; that is, a specific level of naphthalene-acetic acid is added to the nutrient in the absence of all cytokinin.

Besides the practical implications of the discovery, the results have basic significance in that they suggest possible mechanisms for controlling root and stem development.

Walnut Quality

In a trail-blazing hardwood quality study, FPL scientists, in cooperation with the North Central Forest Experiment Station, are conducting an intensive laboratory analysis of why black walnut grown in one area is preferred over that grown in another. For this investigation, 16 logs were obtained from northern Indiana, reputed for its high-quality walnut, and 16 others from two areas in

FPL technologist Neil Nelson explains to Donald H. Gott, executive director, American Walnut Manufacturers' Association, how spectrophotometer measures color in a black walnut sample.
M 133 464 No. 4

Missouri, producing walnut regarded as of lesser value. Samples of soil in which the trees grew were also obtained for analysis of their nutrient content and its possible effect on walnut value criteria.

Quality determinants being assessed include cell structure of the wood, shrinking and swelling with changes in moisture content, and machineability as measured by such operations as planing, turning, shaping, and sanding. All of these characteristics can be measured and evaluated in physical terms reasonably free from subjective judgments.

Another characteristic that has a strong influence on the preferability of black walnut is color. This quality criterion is commonly expressed in subjective terms such as dark brown, chocolate brown, pinkish, and the like. FPL scientists, however, are employing a spectrophotometer to measure color variation in terms of reflected light values that are physically measurable. Among these are the principal wavelength of the light reflected by wood of a given color and the intensity of the reflected light as a measure of color darkness and brightness.

All of these characteristics are being considered in association with the results of the soil analyses to determine what effects soil nutrients and minerals may have on cell formation, dimensional stability, machineability, and of course color. Results have already shown real differences in brightness between Indiana and Missouri samples, the Indiana walnut being brighter.

In another walnut quality study (first described in the 1965 Annual Report and also in cooperation with the North Central Forest Experiment Station), the effect of soil fertilization on trees of various age classes is being investigated. A nitrogen fertilizer was scattered on the ground under some trees at a prescribed rate, while other trees of the same size in the southwestern Wisconsin stand were left unfertilized. Eventually, all trees will be felled and analyzed for fertilization effects on the various wood quality determinants noted in the previous study. Meanwhile, measurement of diameter growth gains made in 1967, two years after application of the fertilizer indicated fertilized trees averaged 34 percent more growth than the unfertilized trees. Natural fertility of the soil in which the tree grew had a pronounced effect on fertilization influence. Fertilization had a much greater effect on trees growing in poor uphill soil. One tree showed a phenomenal 141 percent greater growth than the average for the control trees.

The true worth of fertilization will of course be determined only when the trees have been felled and their wood analyzed for quality as affected by growth stimulation through fertilization.

Wood Density-Quality Surveys

The Nationwide surveys of wood density in standing timber, which originated in the South a decade ago, were extended into the Lake States during 1967 with the start of a Wisconsin survey. The information thus far obtained has proven of enormous value to timber owners and managers, lumbermen, pulp and paper manufacturers, and others concerned with growing and utilizing wood. The importance arises because density is a reliable index of strength, stiffness, fiber content, and other wood properties and characteristics.

The Wisconsin survey, expected to take 3 years, is being conducted by forest survey crews of the North Central Forest Experiment Station and the Wisconsin Department of Natural Resources in cooperation with FPL. As in surveys throughout the South and West, cores bored from standing trees are shipped to FPL for specific gravity determination and other analyses. In addition, FPL crews are obtaining disks of wood from various heights in trees to make whole-tree estimates of specific gravity variation for the species being sampled. These are jack, red, and eastern white pine, quaking and big-tooth aspen, balsam poplar, white and black spruce, balsam fir, tamarack, and eastern hemlock.

As the year ended, a final report on the Maine density survey was nearing completion. This work was done in cooperation with the University of Maine, the Northeastern Forest Experiment Station, and industry of that State. The report covers eight coniferous species, giving means, ranges, and other pertinent information for both core and tree specific gravity.

In the South, only one state, Tennessee, remains to be surveyed. Information on southern pines in South Carolina is being obtained from increment cores collected there during the year. Core collections will be completed in that State this year.

In the West, whole-tree sampling work was done on several important species of pine: ponderosa, western white, lodgepole, and sugar. Analysis of cores of these species for specific gravity had been completed earlier.

Meanwhile, an intensive study of the causes of specific gravity variation in Douglas-fir was completed by an FPL technologist, Laurence E. Lassen, in partial fulfillment of the requirements for a Ph.D. from the University of Michigan. Previous density survey work had failed to show, on the basis of geographic locations, any clearcut reasons for the considerable variation found—often from nearby sampling sites.

Dr. Lassen studied the effects of localized summer precipitation and elevation above sea level on samples of summerwood grown at 45 locations on the eastern slope of the Cascade Mountains from southern Oregon to northern Washington. Effects of elevation were about as expected. That is, the trees higher up on the mountain slopes, to about 3,000 feet above sea level, produced the lighter wood.

Results of the rainfall effects on specific gravity, however, did not conform to the expected pattern. The heavier wood was generally produced on the drier plots. This finding contradicted results earlier obtained in the relatively flat terrain of the South, where specific gravity increased with precipitation over a broad geographic range.

One reason for the difference is the fact that rainfall patterns are entirely different along the Pacific Coast. North-South climatic differences are minimal. Instead, local differences due to the mountainous topography can be great.

From this study, Lassen concluded that as much as 31 percent of the variation in specific gravity of Douglas-fir from the area sampled is associated with summer rainfall. Adding the effects of elevation, he accounted for 53 percent of the total variation. When the effects of the soil's moisture-holding capacity were also added, some 62 percent, or about two-thirds, of the total variation in density was accounted for. The findings are expected to prove highly useful to foresters, timber owners, and producers of lumber, plywood, paper, and other forest products.

Aphid Attack on Grand Fir

The juice-sucking propensities of aphids on the stem can seriously affect the quality of wood produced by infested Grand fir trees, a study has shown. Wood formed following infestation had wider growth rings, a greater percentage of summerwood, and higher specific gravity than normally expected in this species. Modulus of elasticity, a measure of the stiffness of wood, was markedly reduced. Longitudinal shrinkage, normally quite low, was significantly increased. In infested wood, fibril angle was greater and fiber length shorter, both of which are undesirable trends in pulpwood. The wood also had a lower percentage of total sugars and a higher percentage of lignin than normal Grand fir.

Wood Identification Services

A murder trial and a training course conducted in La Molina, Peru, marked the record-breaking 1967 work program of FPL's wood structure and identification specialists. The year set a new record for wood identification requests from nongovernment sources, 752 as compared with the 1966 total of 678 and the previous record high of 747 in 1965.

Dr. Robert Koeppen was called to testify in a Waukesha, Wis., trial of a man for killing his wife. Tree needles found on the slain woman were identified by Dr. Koeppen as spruce and ponderosa pine. Trees of both species — the latter rare in this part of the United States — grew on the grounds of the couple's home, where the murder was committed.

Dr. B. F. Kukachka, head of FPL's wood structure and identification service, spent 4 weeks at the Peruvian Forest Products Laboratory instructing personnel in wood anatomy, identification, and anatomical features affecting wood quality and utilization. For some years Dr. Kukachka has conducted an identification study of Peruvian trees in cooperation with the Peruvian Forest Service. Several hitherto unknown species have been discovered, two of which are named in his honor. The work is supported with so-called 'counterpart' funds obtained through sale of surplus agricultural products in that country.

Stain in Red Oak

At least one type of stain that is costing producers of red oak for flooring and other products millions of dollars annually is probably due in large part to soil type, FPL scientists have found. Silt and clay soils that receive ample amounts of ground water appear especially likely to cause some species

Did he? Or didn't he? A collector of curios put that question to FPL regarding the likelihood that Frontiersman Daniel Boone actually carved his name on this ancient weathered board. The opinion of Dr. Robert Koeppen, FPL wood identification specialist: Could be.

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of red oaks to develop so-called "boundary" stain, which forms in the sapwood-heartwood boundary. Especially susceptible are northern red oak, black oak, pin oak, Nutall oak, and laurel oak. Willow oak is less likely to develop the stain, and there is little or no tendency toward it in cherry bark oak and the white oaks.

The differences in susceptibility among oak species indicate that genetics, as well as soil, may play a part. Oak seedlings sprouted from acorns of various species gathered in northern Michigan, Wisconsin, Kentucky, and Illinois are being grown in University of Wisconsin greenhouses for further experiments. Some of these will be inoculated with bacteria and fungi found in association with stained wood, to ascertain whether there is a causal relationship here.

Laboratory cultures of bacteria and fungi obtained from stained wood are also under study to learn whether they are responsible for some of the stains found in the wood. The rancid odor of some stained oak appears to be associated with bacteria. It is known that oak lumber with this rancid odor invariably honeycombs seriously when air dried or kiln dried under normal kiln schedules.

INFORMATION ACTIVITIES

In printed media, television, and radio, on motion picture film, and in talks and exhibits for technical, scientific, and laymen's groups, the work of FPL was comprehensively reported during 1967 to keep others informed.

The most heavily used avenue of FPL information activity is the research report. In general, three broad categories are employed: the formal written document published as a research paper or research note by the Laboratory; the article written for a scientific, technical or trade journal; and the spoken address delivered before a scientific or industrial audience. Occasionally a more comprehensive publication is issued on a given field of research and development through the medium of the U.S. Department of Agriculture publication series. In 1967 a Laboratory publication, "Selection and Use of Wood Products for Home and Farm Building," by L. O. Anderson, was published as USDA Agriculture Information Bulletin No. 311.

An even dozen Forest Service Research Papers were issued by FPL during 1967, together with a somewhat different category called Research Notes, of which 23 were printed. Comprising by far the largest category of publications, however, were the scientific and technical articles that appeared in many professional and trade journals; in all, 60 were printed during the year.

Staff members presented 36 papers, lectures, and seminar discussions at meetings ranging from highly technical to college classes and industry groups. Prominent among these were the Forest Products Research Society annual meeting at Vancouver, B. C.; the Technical Association of the Pulp and Paper Industry annual meeting in New York City; two national meetings of the American Chemical Society, at Miami Beach and Chicago; and national meetings of the Architectural Woodwork Institute, the National Hardwood Lumber Association, the Hardwood Dimension Manufacturers Association, and the American Phytopathological Society.

Many important regional meetings programmed FPL speakers. These included a Wood Machining Seminar at Richmond, Calif.; the Midwest and Wisconsin-Upper Michigan Wood Seasoning Associations; the Southern Forestry Conference at New Orleans; a Wood Chip Storage Symposium at Camas, Wash.; and kiln drying workshops at the University of Idaho and North Carolina State and Mississippi State Universities.

Other organizations to hear FPL speakers included the Furniture Manufacturers Association of Grand Rapids, Mich.; the Society of Packaging and Handling Engineers; the National Fibre Box Association's Western Division; the Philadelphia Section, National Association of Corrosion Engineers; Trees for Tomorrow workshops at Merrill and Eagle River, Wis.; the Chicago Gas Chromatography Discussion Group; the Rocky Mountain Forest Industries Conference at Fort Collins, Colo.; a TAPPI Alkaline Pulping Conference at Mobile, Ala.; and the American Society of Civil Engineers Structural Conference at Seattle.

Joseph A. Liska, Chief of FPL's Division of Wood Engineering Research, was chairman of a United States national committee for the International Council for Building Research in Washington, D.C. Staff members also spoke to students at the University of Washington Forestry School; the University of California at Los Angeles; the University of Wisconsin-Milwaukee; La Crosse, Wis., State University; Purdue University, and the University of Toronto, Canada.

Several staff members traveled far abroad to speak. Dr. B. F. Kukachka, in charge of FPL wood identification and structure research, gave a series of lectures at Lima, Peru, to Peruvian Forest Service and industry personnel. John F. Lutz, wood machining research technologist, presented a paper at the Munich, Germany, Congress of the International Union of Forestry Research Organizations. Alan D. Freas, Chief of FPL's Division of Solid Wood Products Research, presided over a meeting of Section 41, Forest Products, at the IUFRO Congress. He is deputy chairman of the Section.

The laboratory was host to several scientific meetings. The Phytochemical Society of North America brought about 120 plant chemists to Madison for its annual meeting, which included a tour of FPL. About 100 met at FPL for the biennial Lake States Tree Improvement Conference. Some 200 members of the Midwest Society of Electron Microscopists and their guests attended the society's annual meeting.

Numerous industry meetings were held at FPL:

January: Steering Committee on Fire Retardants, American Wood-Preservers' Association; Task Group for Evaluation of Primers for treated Millwork, National Woodwork Manufacturers Association.

February: Task Force of the Standing Committee, Federal Council for Science and Technology; Forest Service Timber Bridge Workshop; Design Seminar for Architects.

March: Training session in forest products technology for group sponsored by the Southern Pine Association; liaison committee of National Forest Products Association and National Paint, Varnish and Lacquer Association.

April: Panel Products Industry Liaison Committee; industry meeting on properties of southern inland Douglas-fir.

May: Advisory Committee on Waste Disposal of the Wisconsin Pulp and Paper Industry.

June: Preservation and Priming Subcommittee, National Woodwork Manufacturers Association.

August: Technical Committee, American Wood-Preservers' Institute.

September: Industry meeting on fire behavior in plywood.

Technical Committee of the Fibre Box Association and Industry Committee on Corrugated Fiberboard Research; Committee D-7, Wood, American Society for Testing and Materials; Subcommittee on Hardwoods, National Forest Products Association; Committee on Technical Studies, NFPA.

October: Technical Committee, American Hardboard Association; Fibre and Particle Panel Liaison Committee; Pulp Chemicals Association; Great Lakes Industrial Development Council; Publicity Committee, Forest Products Research Society and Society of Wood Science and Technology.

November: Technical Conference and Dedication of Wood Fiber Products and Wood Chemistry Research Facilities at FPL; Research and Development meeting of Home Manufacturers Association.

The technical conference that preceded the dedication ceremony for the new FPL buildings November 8 brought about 100 research officials of industry and educational institutions to FPL. Dr. H. O. Fleischer, FPL Director, welcomed them, and FPL scientists presented a series of papers discussing current research.

Necmi Sanyer, chemist in charge of pulping research, described objectives for which the new facilities will be used. Among research goals he listed are new pulping processes that will increase tonnage yields from wood while eliminating air and water pollution.

"The most significant progress in pulping technology," he predicted, "will be made with the discovery of new and more selective reactions of wood components, particularly lignin. The research objective should be directed toward the use of active agents that could be derived from the abundant elements in air and water."

Dr. John M. Harkin, in charge of FPL lignin research, said the molecular structure of this major component of wood is becoming well defined, opening new possibilities of devising processes for breaking its huge molecules into smaller ones more easily removed from wood without drastically altering them.

Harold L. Mitchell, Chief of the Division of Wood Quality Research, warned industry leaders that overspecialization in a single line of scientific research can hamper industrial progress. Persistent communication of research results can, he said, break down barriers that result from such overspecialization. FPL's nationwide wood density surveys of standing timber have functioned thus, he said, to bridge gaps between timber growers and breeders and the producers of lumber, plywood, paper, and other products by bringing out the close relationship between wood quality and such factors as rainfall, soil, and climate.

Gardner H. Chidester, who had retired as Chief of the Division of Wood Fiber Products Research September 23, presented a comprehensive review of Forest Service research in his area of specialization. His successor, Richard J. Auchter, gave a detailed description of the new facilities for pulp and paper research. Mr. Auchter came to FPL in June with an extensive industrial research background.

A comprehensive overview of Forest Service research was presented by George M. Jemison, Deputy Chief in charge of research, Washington, D.C.

Other speakers at the technical conference were Richard A. Horn, pulp properties specialist; Dr. Wallace E. Eslyn, pathologist; Vance Setterholm, technologist in charge of paper properties investigations; Dr. John W. Rowe, chemist in charge of research on wood and bark extractives; Dr. Harold Tarkow, Acting Chief of the Division of Wood Chemistry; and W. G. Youngquist, Assistant to the Director.

From Near and Far They Came

Of the 12,170 visitors who came to FPL in 1967, those with specific consulting missions numbered 3,937. Both totals were the largest in some years.

In all, 351 came from 49 foreign countries on every continent. From next-door neighbor Canada came the largest single contingent, 59. France sent 41, Brazil 37, Japan 28, Sweden 26, Cambodia 14, England 11, and Germany 10. Other countries represented were Argentina, Australia, Belgium, Cameroon, Channel Islands, Chile, Colombia, Czechoslovakia, Denmark, Finland, Ghana, Holland, India, Indonesia, Ireland, Italy, Jamaica, Kenya, Liberia, Libya, Malagasy Republic, Malaysia, Mexico, Nepal, New Zealand, Nigeria, Norway, Pakistan, Peru, Philippines, Poland, Republic of China, Republic of South Africa, Romania, Ryuku Islands, Scotland,

Singapore, Switzerland, Thailand, Turkey, and Uruguay.

Eighty-five of the foreign visitors coming to FPL were sponsored by the Agency for International Development and seven by the United Nations Food and Agriculture Organization.

Guided tours were taken by 6,001 casual visitors, most of whom arrived for the daily scheduled tour at 2 p.m. The most popular months were May, June, and August.

Educational Activities

The dissemination of research results is primarily an educational function, whether it be done by the simple act of sending out a publication, by giving an informal talk to a lay group, or by directly participating in formal educational activities. FPL staff members utilize all such avenues of dissemination—and in both directions. Information and training are acquired as well as given.

Two FPL scientists did advanced academic work under the Federal Employee Training Act; a third did similar study under a National Science Foundation traineeship. Eugene M. Wengert spent the year at Colorado State University studying advanced wood technology, thermodynamics, and climatology as training for his FPL research in environmental effects on wood and wood products. Von L. Byrd enrolled at North Carolina State University for studies in cellulose polymer chemistry to improve his capability in wood fiber products research. The NSF traineeship took A. Carl Maki to Michigan Technological University for advanced engineering studies.

A fourth staff member, Dr. Margaret K. Seikel, left in October for advanced research on the molecular structure of hydrolyzable tannins at the laboratories of the Australian Commonwealth Scientific and Industrial Research Organization's Division of Forest Products in Melbourne.

With Whitten Act funds provided by Congress, FPL underwrote seven graduate research projects at universities. At Iowa State University, a study on the effects of soil fertilizers on cottonwood was supported. A graduate student conducted research on xylem formation in red oak at the University of Michigan. Wood permeability in relation to the drying of hardwoods was under investigation at North Carolina State University. At the State University of New York, Syracuse, a graduate student pursued studies of hydrogenation pulping, and at the University of Washington another worked on the kraft delignification pattern of typical softwood and hardwood species. A student at Colorado State University did engineering study on layered wood plate systems with interlayer slip, and at the University of British Columbia another explored the chemical constituents of spruce wood.

Under terms of a long-standing cooperative agreement with the University of Wisconsin, five students did research at FPL in conjunction with campus graduate study. Two worked in the field of wood quality, and one each in solid wood products, wood engineering, and wood chemistry.

The 92nd dry kiln demonstration conducted by FPL scientists was attended by 44 men April 3-14. In recent years this demonstration has been conducted on an annual basis, although its genesis goes back to 1919.

Exhibits

Unusual exhibits were sent to two major professional meetings during 1967. One, depicting the role of forest products research in establishing industries in rural America, was displayed at the annual meeting of the Society of American Foresters in Ottawa, Canada. The other, devoted to research on lignin and its potential benefits, was shown at the U.S. Department of Agriculture's Science Fair in Beltsville, Md. A variety of exhibit material explaining various phases of FPL research was also prepared for dedication ceremonies of new buildings at FPL November 7-8.

List of Publications

The list of publications appended to Annual Reports of previous years is omitted from this 1967 edition. You may obtain the same information from our semiannual lists of publications, copies of which are available on request for both 6-month periods of 1967.

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